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TECHNICAL SCHOOL ORGANIZATION AND TEACHING

C. HAMILTON

WITH A PREFACE BY

G. UDNY YULE

EDITOR OF THE SERIES

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EDITOR'S PREFACE.

RAPID changes have been taking place during the last few years in the organization of Technical Education in Evening Schools. The abolition by the Board of Education of examinations in certain subjects and of the elementary examinations in all subjects, the encouragement of internal tests in lieu of external examinations, the increased attention that is being paid to the formation of group courses instead of the old courses in single subjects, while in many respects giving greater freedom to both teachers and organizers, have thrown on them increased responsibilities, and presented them with new problems for solution. In arranging, therefore, for a new series of text-books better adapted in some measure to the existing circumstances it was thought desirable to provide an Introductory Volume on organization and teaching in the Evening Technical School. Mr C. Hamilton, whose articles on the Teaching of Practical Mathematics, Science and Drawing in the *Practical Teacher* during 1909-10 will be known to some of our readers, was so good as to undertake this volume. He has discussed therein the work to be effected by the Technical School, its internal organization, the arrangement of courses of instruction, and the function of examinations. He has here dealt with the general principles of teaching, and, taking a few of the principal subjects, has considered in some detail the particular methods to be adopted. Mr Hamilton possesses a very wide experience of Technical Schools and expresses his views with vigour and

lucidity: it is to be hoped, therefore, that teachers and organizers will find the volume both helpful and stimulating.

In the arrangements for the text-books of the series special attention has been paid to the requirements of the course system. Thus, for the First Year Course for Building Trades students, three volumes are provided on Building Construction, the Geometry of Building Construction, and the Science of Building and Building Materials respectively. For the First Year Course for engineers there are similarly three volumes of Machine Construction, Practical Mathematics, and Applied Mechanics, and arrangements will be made for groups of text-books similarly adapted to the requirements of students in other trades. It is hoped that the series may do something to assist teachers in the reorganization of their courses in accordance with the present requirements of educational and industrial progress.

G. UDNY YULE.

AUTHOR'S PREFACE

IT seems to be the fate of Evening Technical Schools to suffer a violent cataclysm every ten or twelve years. The Technical Instruction Act of 1890 did much towards the provision of buildings and equipment, and the Education Act of 1902 made Continuation Schools available for the first time as centres of preliminary training. Throughout the first period systematic and progressive courses of instruction were talked about, and about 1901 a few were established. The second period has witnessed an enormous growth of systematic instruction and of laboratory provision.

Within the past year the examinations in the elementary stages of science subjects, which have been held without intermission for half a century, have been abolished, and the schools have entered upon a period of wider freedom and heavier responsibility. For some years the development of the course system and of an organization which would bring the schools into closer touch with local requirements has been hampered by the traditions of examinations and of text-books the scope and character of which were determined more by the examination syllabuses than by the needs and capacity of the students. The appearance of a new series of text-books was felt, therefore, to offer a favourable opportunity to provide, more especially for the younger generation of technical teachers, a little volume which discusses briefly the chief problems that have to be faced, and the best methods of solving them.

The book is divided into four parts. The first discusses the nature and purpose of Evening Technical Education; the second deals with Organization; and the third attempts to present, in a simple manner, a few of the general scientific principles which underlie sound methods of instruction. The fourth part consists of notes and suggestions on the teaching of some of the subjects commonly found in the lower section of Technical Schools. The last chapter advocates the training of technical teachers, and is followed by a series of questions on method.

During its preparation and in its passage through the press the various chapters have been read and criticized by a number of competent authorities, including most of the writers of the earlier books in the series. To these the author offers his gratitude and his apologies. He has adopted with pleasure as many as possible of the practical suggestions which were not in conflict with his own experience or with the established principles of modern psychology.

C. HAMILTON.

CONTENTS

PART I.—INTRODUCTION

CHAPTER I

THE MEANING OF TECHNICAL EDUCATION

CHAPTER II

EVENING TECHNICAL SCHOOLS AND THEIR WORK

PART II.—ORGANIZATION

CHAPTER III

THE HEADMASTER, THE STUDENTS, AND THE STAFF

CONTENTS

CHAPTER IV

THE ARRANGEMENT OF COURSES OF INSTRUCTION

CHAPTER V

EXAMINATIONS AND OTHER MATTERS

PART III.—TEACHING

CHAPTER VI

GENERAL PRINCIPLES

CHAPTER VII

SKILL

CHAPTER VIII

THE MINOR DETAILS OF TEACHING

PART IV.—NOTES AND ILLUSTRATIONS OF SPECIAL METHOD

CHAPTER IX

THE PRELIMINARY TECHNICAL COURSE

CHAPTER X

MATHEMATICS

CHAPTER XI

EXPERIMENTAL SUBJECTS

CHAPTER XII

THE TEACHING OF CONSTRUCTION

CHAPTER XIII

THE TRAINING OF THE TECHNICAL TEACHER

APPENDIX

PART I

INTRODUCTION

TECHNICAL SCHOOL ORGANIZATION AND TEACHING

CHAPTER I

THE MEANING OF TECHNICAL EDUCATION

TECHNICAL Education, in the proper meaning of the term, is as old and older than learning itself. From time immemorial man has manifested a desire to train his offspring in those arts which enable them to live and to get a living. As knowledge was accumulated and became ordered and systematized the parent spared no pains to hand down to the children the dearly-won lore of their ancestors. A knowledge of wood-craft, of agriculture, of construction for protection from weather and defence against enemies, and of other matters which determined man's existence in those days, was religiously communicated from father to son. Then, as men congregated into larger groups, as commerce arose out of primitive barter, as towns grew up, as human life became more complicated, the parent gave more and more time to the state and less to his family. But even in the Middle Ages, when training outside of the most primitive type was undertaken, when the main interests of life were divided between War and the Chase on one hand, and the Law, the Church, and Government on the other, the parent retained under his closest supervision the instruction of the boy in the manly arts, while he handed him over to the scholar for

instruction in language and philosophy. The purpose even here was obviously technical. As commerce gained ground and threatened the supremacy in numbers and power of the Law and the Church, the need for book learning became wider, and the parent threw upon the scholar the responsibility for more and more of youthful training. But the scholar lived in relative retirement; he was *in* the bustle and whirl of industrial and commercial progress, but not *of* it; what he learned to value most in life was what men had thought and done in the past, not what men were thinking and doing in his own day or would think and do in the future. Thus there arose a system of education remote from immediate needs, availing itself but little of existing circumstances, and providing a pitifully insufficient training for the future.

While this training had met the apparent needs of the learned professions and politics (the traditional occupation of leisure), it has done but little to provide either for the progressive conduct or for the intelligent interpretation of the modern world.

It is not intended to convey the impression that all schools should be technical schools, offering a narrow and highly specialized form of training. In earlier days the social structure was simpler, the range of knowledge less, and future needs could be predicted with greater certainty than in our time. There is now a great deal more of what may be termed common heritage, but tradition still hampers the establishment of a reasonable balance between the old and the new requirements.

During the last few years some attempt has been made to deal with school pursuits from the standpoint of environment, but progress towards a curriculum which shall be based upon an accurate estimate of the balance of studies in relation to environment is slow and uncertain.

It has been admitted that the complexity of modern life and the vast heritage of common knowledge render it impossible to attempt any high degree of specialization in the ordinary

elementary or secondary school course. Specific training for particular occupations—industrial and professional—must therefore be obtained subsequently. Such special training, given after a boy has left school and entered upon, or at least chosen, his career, is called Technical or Professional Education.

The full business of training for life is therefore divided into two stages, one general, and the other, undertaken at a later stage, special. In both cases the real motive is training for the common service. Every parent probably might not unfairly be accused of desiring to do the best for his own son, but a claim based solely on individual gain could not receive public support. The association of many parents destroys the selfish individual motive, and merges each individual hope or desire into a communal interest and aim.

The characteristic of a national system of education then is the implied principle that the individual can only profit indirectly through service to the community as a whole. Industries differ widely in the extent to which the men engaged in them require technical training, and in the nature of that training. Many depend very largely upon the manual skill of the workman, and in these the method is to train craftsmen—to give them a knowledge of the materials and processes used in their trade. At one time—thirty or forty years ago—this was held to be the real and only function of Technical Education, and it is supported even to-day by arguments which depend for their validity upon the necessity of an apprenticeship system. But outside a few crafts, apprenticeship has fallen into desuetude. Certainly attempts are continually being made to revive it, but without much success. And the reason is not far to seek. So long as an industry depended upon the individual skill of a large proportion of men engaged in it, the master found it necessary to train the young people who came to him, and equally to protect himself by requiring them to serve him for a certain number of years. But the small employer with a limited number

of men has been replaced by the large company employing hundreds or thousands of workmen, machinery has been introduced which performs more quickly and economically the work of skilled craftsmen, and workshop processes have been so subdivided that a boy can acquire sufficient skill in a narrow groove in very short time.

Side by side with the decreased need for the training of the workman, has arisen an increased need for the training of those who supervise industrial occupations. The use of machinery and of electrical power, the manipulation of large quantities and weights of material, and the high pressure at which industrial operations are carried on, renders exact knowledge of machinery materials and processes a *sine quâ non* to the foreman and manager. Moreover, the interdependence of industries, the prevention of waste, the use of new materials and processes, demand a broad scientific knowledge as the vital force of almost any and every mining or manufacturing concern. The extraordinary growth of scientific knowledge and its application during the last twenty years has indeed rendered a long and comprehensive university course an essential qualification for many industrial positions, but it has not decreased the need for scientific and technical knowledge on the part of many who cannot hope for and do not require the wider training. It is with this latter class in the main that the evening technical school deals.

It is only according to the natural order of things that this demand for scientific training should over-reach itself. The pendulum has swung too far. Under the stress of industrial competition the application of science to industry is limited by other considerations. The experimental method, requiring time, and courting failure as a prelude to success, is often faced with opposition from the conservative attitude corresponding with the old adage: " A bird in the hand is worth two in the bush." The scientific man has not ousted, and never will oust, experience

and organizing ability combined with a reasonable amount of knowledge and common sense. Ninety per cent. of the success of any industrial concern depends upon organizing ability, personality, business qualities, and other things which are to be acquired in no university and in no school other than that of experience.

There is no doubt that Technical Education of all grades in this country is highly academic, and it is mainly this feature that leads many men to express the opinion that the boy who is entering industrial life ought to go from school to the university, and then into the works. The whole argument in favour of this view rests upon a plea for continuity of study. On the other side is a whole array of important considerations. First and foremost the schoolboy is too immature to grasp the broader problems involved in a university industrial course. Secondly, the university teaching requires to be interpreted in the light of economic and industrial conditions. The professor lives in the clouds—and rightly so. That is his place. No man can inspire from a low level. But the student is unlikely to become a professor—it is at least one hundred to one against such a contingency. On the other hand, he may have to take his share in managing a works with a small margin of profit, and he ought to be able to express the value of new materials, modifications of design or process, in dividend. If Technical Education is to receive the recognition which it imperatively demands, it must come closer than ever to industrial conditions.

The only serious objection to the college course being delayed until after a period spent in the works, is the strain involved in attending evening classes. To this argument some consideration must be given. But it should be borne in mind that the classes are only held during the winter months when the nights are often cold, wet, and cheerless, and that an extraordinary number of students successfully accomplish the task. They

exhibit not only capacity, but also that perseverance which is so great a factor of success in life. But whichever system is the best may be regarded as immaterial to our purpose. An overwhelming majority of the captains of industry have obtained, and will continue to obtain, their training in Evening Technical Schools, and we must now pass to a consideration of the work of these institutions.

CHAPTER II

EVENING TECHNICAL SCHOOLS AND THEIR WORK

EVENING classes bearing on industry owe their existence to two events. The first was the establishment by the Prince Consort of the Science and Art Department after the Exhibition of 1851. This Department conducted examinations, trained science teachers, and aided science and art classes. The other event was the establishment by the City Livery Companies of the City and Guilds of London Institute. The classes conducted under the auspices of these bodies are so well known, and their recent history is so familiar to those who conduct Evening Technical Schools as to render further reference to them unnecessary. Before passing to a consideration of organization and teaching it will be sufficient to deal briefly with two other movements of fundamental importance.

For more than thirty years the technical teacher has bewailed the fact that the students who come to him for instruction are inadequately prepared to profit by his teaching. The elementary school rarely provides a satisfactory foundation for technical study. Moreover, technical teaching, as distinct from elementary mathematics or geometry or physics, demands an acquaintance with the environment of a workshop which the raw schoolboy does not possess, and it can rarely be conducted effectively with boys under sixteen years of age. But until 1901 Technical Schools under the Technical Instruction Committees were unable to obtain grants upon subjects outside the

Directory of the Science and Art Department, and Continuation Schools, or Night Schools, as they were called, were under the School Boards. These two bodies were mutually distrustful, and co-operation was conspicuous by its absence. What was wanted, and what could not be obtained, was some instruction suitable for boys between fourteen and sixteen years of age, which would provide a basis for subsequent technical study.

Meantime another problem arose in the Technical Schools. Students chose unsuitable subjects of study, and met with difficulties owing to the fact that many of these subjects are logically interdependent. All technical subjects pre-suppose some foundation of pure science, but the technical title appeals to the student, and the soundness of the teaching suffers from the lack of this scientific foundation. For a number of years the Science and Art Department—who paid on examination results—would only pay grant on two successes in science in addition to mathematics and geometry. The regulation of the Science and Art Department did not, however, secure that a student took mathematics or any other essential subject.

The City and Guilds of the London Institute was faced with a similar problem. The necessity of a scientific or artistic basis to trade subjects was recognized in their regulations, and a student who had passed a technological examination in the honours grade could not obtain a full technological certificate unless he had also passed the examinations in certain subjects of science or art from a given list. The result was that the student passed the technological examination first, and then cast about for the easiest science or art subjects required for the full qualification. To remedy this the City and Guilds of London Institute established a preliminary grade to certain subjects, a pass in which was required before the ordinary grade was attempted. The plan was effective over a limited field.

EVENING TECHNICAL SCHOOLS AND THEIR WORK

The need for a curriculum covering the whole requirements of a student, in which the subjects are arranged in logical order, was emphasized in the Report of the Royal Commission on Technical Education of 1882-4, and in the late nineties many Technical Schools printed courses of study in combinations of subjects in their prospectuses. There was, however, but little compulsion to take these courses.

The passing of the Education Act of 1902, however, was the signal for the advent of a new policy. So long as the Technical and Continuation Schools were under different controlling bodies, the Technical Schools could not be sure that preparatory training of the right sort was provided in the Continuation Schools, or that students would be encouraged to pass forward from the lower to the higher schools. Until they could be assured on these points they were reluctant to exclude students who came to them inadequately prepared. But when both sets of schools came under the same local authority the two problems—the external and the internal—were attacked with energy and success.

In the first place, there was established in the Continuation Schools what is known as the Preliminary Technical or Industrial Course. This consists of English, Elementary Mathematics, Technical Drawing, and either Science or Woodwork. Attendance is required as a rule for three nights a week for two years, but a smart elementary schoolboy is frequently allowed to enter the second-year course direct. This scheme has reached its highest development in the north of England. In Lancashire and Cheshire it owes its success largely to the influence of the Lancashire and Cheshire Union of Institutes, which established course examinations in place of those formerly held in single subjects. In the West Riding of Yorkshire the County Education Authority conducts its own examinations. Some idea of the progress made can be obtained from the statement that in March 1911 the number of students taking the Preliminary Technical

Course Examination of the Union of Lancashire and Cheshire Institutes was 9,308, as compared with 7,851 in 1910.

In view of the large number who are receiving preliminary technical training, some disappointment may be felt at the small number who reach the Technical School by this avenue. But it must be remembered that the Continuation School has to provide for many who cannot hope to profit by technical instruction. The tendency of industry is to demand a higher standard from fewer men, and the boys are quick to recognize their limitations. The real value of the innovation, however, lies in the fact that the existence of the preliminary course enables the Technical School to insist on a standard of admission. From enquiries which have been made it appears that it is usual for this standard to be maintained in respect of all students under sixteen. Students over that age are usually diffident about attending Continuation Schools with younger students, and for them many Technical Schools have a modified preliminary course to which students under sixteen are not admitted.

The second problem, which has come within measurable distance of solution since 1902, is the replacement of single subjects by progressive courses of instruction in groups of scientific and technical subjects. Schemes of study covering three evenings a week are now arranged in most Technical Schools. Each scheme assumes a knowledge of the Preliminary Technical Course, and secures a broad comprehensive training bearing upon some occupation which provides a sufficient number of students to justify the establishment of the Course.

Notwithstanding the progress which has been made during the last ten years, there is still much misconception as to the meaning of the term Course. The course system is a mode of organization of a school to enable it to meet the industrial needs of the area it serves in the most efficient and economical way. It is not designed to meet the technical or professional

requirements of any individual, but those of a group of individuals; it would be manifestly impossible for many schools to arrange courses for each of the enormous variety of interests which exist in the neighbourhood. There must always be a number of students unprovided for in the scheme, and each case has to be met so far as the organization of the school will allow. Some concession always has to be made to adults. The man of full age has frequently had inadequate preliminary training; he is liable also to certain civic responsibilities, to the exigencies of parenthood, to the cares and duties of a householder, and to more stringent industrial or professional ties, than the younger man. And if he cannot attend the whole course, it is usual to relax the regulations as to admission and attendance in his case. But neither the isolated student nor the adult affect the course system as a system of school organization.

This system has an important effect upon the scope of the so-called subjects of instruction. For many years the science classes were dependent upon examination results for their existence. Even after the Government grant ceased to depend upon the results of the examinations, the latter continued to exert a dominating influence on the work of the schools—an influence which was re-inforced by the fact that practically every text-book was written upon the examination syllabus. The obstacles which stood in the way of the course system may be gauged by a consideration of engineering subjects. Classes which may be regarded as bearing directly upon the work of the engineer were held in Mathematics, Practical Mathematics, Practical Plane and Solid Geometry, Machine Construction and Drawing, Theoretical Mechanics (solids and fluids), Applied Mechanics, Heat Engines, and Mechanical Engineering under the City and Guilds of London Institute. The selection of subjects to form a suitable course which would include appropriate laboratory instruction was a matter

of considerable difficulty. Courses varied in different schools merely because of differences of opinion as to the relative value of different subjects. If the examination syllabuses were followed something of relatively small value was sure to be included, and something of relatively greater value excluded.

The precise way in which this has been overcome will be discussed in Part II, but the fundamental principle involved may be stated here. One of the disadvantages of the single subject system was that the weekly lessons permitted six days for forgetting what had been learnt. Where home-work was done this maximum was reduced to five. The fullest advantage of the course is only secured when it constitutes a whole, when the teaching is continuous—not from Monday to Monday, Tuesday to Tuesday, and Thursday to Thursday, but from Monday to Tuesday to Thursday. This ideal can be approached most nearly in the Preliminary Technical Course; for with the exception of English all the subjects can be blended into a single unit in the first year, and into two units in the second year. But beyond the Preliminary Technical Course difficulties arise, and the course resolves itself as a rule into three parallel series of lessons, one on each evening, which permit of ready and natural correlation. Quite apart from details, however, it will be clear that the old single subject system and the course system are in opposition—at any rate, in the earlier stages of the work. As the student progresses it becomes imperative for him to concentrate upon narrower lines, and it is the necessity for a broad basis in the earlier years that often leads to the conflict of studies.

It has been stated, and the statement will bear repetition, that the course system is a system of *school organization*, and that it enables the Technical School to meet the industrial needs of an area. A good deal is implied in this definition.

In the first place it assumes that the Technical School authorities have an exact knowledge of the nature of the prin-

cipal local industries, of the number of men engaged, of the various grades of employees, of the work which each grade is required to do, of the kind of instruction which will enable the men to carry out that work most effectively. Moreover, it assumes that the necessity for technical training is recognized by the employer no less than by the public which from national and local sources provides the money for the establishment and maintenance of Technical Schools. This recognition carries with it the obligation to provide facilities for young men training for the common service. It must be admitted that the spectacle of a great nation providing a system of Technical Education, and the employers of that nation presenting such obstacles as to render the system wasteful and inefficient, is too truly Gilbertian to be contemplated with equanimity.

Every year sees a greater readiness on the part of employers to give not only facilities but direct encouragement. Perhaps the payment of fees by employers does not increase very much, but then there are good reasons for not desiring an extension of this plan. A student who gets a thing too cheaply places a low value upon it, and the too highly subsidized boy is apt to think he is conferring a benefit upon the community in general and the teacher in particular by his attendance. An increase in wages to successful students is always a heavy spur, and it is more than that valuable as indicating that the employer is able to put a price upon the training.

Still, in spite of all this there is a feeling abroad that unless the hours of labour are relaxed the employer is grasping an advantage for himself and for the community by encroaching upon the scanty leisure of the growing boy. If one man in a business can give greater and more efficient service to the community by undergoing training it is manifestly unfair that he should work under conditions which nearly approach slavery. The situation here outlined is sometimes used as an argument against the tyranny of the course system, with its rigid

requirement of three nights attendance and homework. But as a matter of fact the relation of the course system or any other system of Technical Education with the question is purely accidental. The long hours of labour are detrimental to the boy whether the extra six are spent in the Technical School or in recreation. The feeling which is aroused by the requirement that a youth should spend six hours a week in the Technical Schools after fifty-four hours in the factory or workshop ought to operate almost as strongly against long hours at all.

Unfortunately a considerable number of people imagine that the strain of an Evening Technical School course can be relieved in another way. It is suggested that as three nights attendance and homework impose a serious burden upon the average student, the number of nights should be reduced to two. This plea comes principally from those who can have had little experience—and certainly can have little conception—of the difficulty of arranging an educational course requiring an attendance of only two evenings a week during the winter months which shall achieve an educational result worthy of public expenditure. They do not appear to realise that three nights a week attendance — nay more — and homework was undertaken by hundreds of students before the course system ever saw the light, and they do not take into account the fact that the industries of this country, which are as highly developed as in any country in the world, are carried on in the main by men who have passed successfully through the strain of Evening School attendance? And what is, in effect, the alternative? If the course is reduced from three to two nights, the instruction in laboratory work, drawing, and mathematics will have to be curtailed. Out in the world the personal qualities of the man capable of attending, and willing to attend, for three nights a week are bound to tell, and the proposal would render his training less effective than

it might have been. Can it be seriously contended that this attempt at the national endowment of mediocrity would yield beneficial results?

But this question of encroachment upon leisure is not a problem peculiar to the Technical School. If his work is so hard and the hours so long that a boy cannot take advantage of the Evening Technical School, then all opportunities for the intellectual enjoyment of leisure are impaired. If this charge against employers on behalf of the Evening Technical School can be sustained, it becomes merged in the more serious one of purchasing the youth of the nation body and soul for a few shillings a week. Pushed to its logical conclusion, it means that the boy enters the works in the morning and is cast out in the evening capable of nothing but recuperating for the next day's toil

There is no doubt that the employer who desires to give facilities and encouragement is hedged round with difficulties, and he cannot move unless his competitors are prepared to move with him. That is why favourable opinions on the platform are so seldom realized in practice Consequently there is a growing body of public opinion in favour of legislation which shall limit the hours of juvenile labour, and remove many abuses which are distinct from the handicap in Technical Education. Quite apart, therefore, from educational considerations, there are good reasons for the Technical Schools maintaining their requirements of three nights a week and homework. Any weakening on this point merely plays into the hand of the unsympathetic employer, and delays the growth of that public opinion which will, sooner or later, demand proper leisure for the youth of the nation.

But if this attitude is to be maintained the schools must see to it that their own methods are without reproach. They must show that their teaching is directed to the satisfaction of industrial needs, and that it is economical of time, of money,

and of personal effort. They must be prepared to reject schemes which are justified merely by tradition, to embark boldly upon any re-organization which may appear necessary, and to keep themselves abreast of the needs of a progressive community.

PART II

ORGANIZATION

CHAPTER III

THE HEADMASTER, THE STUDENTS, AND THE STAFF

THE course system has added considerably to the importance and responsibility of the headmaster. Formerly his main purpose was to advise intending students as to the work they should undertake, and, in the absence of stringent regulations, this was often a thankless task. But when he had exhausted all the arts of persuasion his function was almost fulfilled. His staff were more or less isolated units, each responsible for the work which appeared under his name in the time-table, and usually indifferent to the work of any or every other teacher in the school.

The first additional task thrown upon the headmaster was that of preparing a time-table which would permit certain groups of students to attend suitably selected classes on three nights a week. It was not possible all at once to introduce properly co-ordinated courses, for in that case some teachers might have had to be discharged and others appointed. Most technical teachers are specialists, they are less adaptable than elementary or secondary school teachers, and occasionally they have vested interests and long service behind them. The revision of syllabuses is therefore often a matter of difficulty. But unless and until the course is regarded as the unit of organization, there can be nothing but an unsatisfactory compromise. The unit is the course, the only possible subdivision is an evening's work, and a mere grouping of subjects satisfies neither educational requirements nor the demands of administrative simplicity.

The next duty which the headmaster has to face is that of persuading the students to take courses. Here again the single-subject organization stood in the way. Most students have a vague notion of what they want, and they naturally prefer subjects with a trade title. But if an engineering course, for example, is advertised as a whole, with engineering calculations on one evening, engineering drawing on a second, and experimental engineering on a third, the student has a smaller element of choice. For an engineering course should not consist of separate and independent classes in Practical Mathematics, Geometry, Drawing, Mechanics, and Heat Engines, but a well-organized teaching scheme including all that is necessary of these subjects for the students who attend.

It is usual to charge a low fee for a course of instruction, and this is only a small proportion of the total cost. This low fee is justified because a student who takes the course is assisting the school to perform its work in the most efficient and economical way. A student who should but does not take a course not only causes the loss of a certain amount of grant—upon which the school authorities counted in fixing the fee—but he lowers the efficiency of a public institution maintained largely by public funds. If he is prepared to pay his share of the cost of maintenance—that is, the average cost of the school per student—he may be allowed to select his own course of study, but not otherwise. The reputation of the school and the best interests of Technical Education demand that the men turned out shall have profited to the full by the training which the school provides. Some cases there always will be in which it is advisable to make concessions, but there is not much to be gained by giving way too freely to the private wishes of individuals.

This question of admission is closely connected with that of subsequent attendance at the full course. The usual plan in case of non-attendance is to send post-cards or circular letters to students who have been absent twice in succession. In some

cases a graduated series of warnings—the later ones hinting more or less definitely at serious consequences—are issued. Sometimes this "post-carding" is delegated to the teachers, and the amount of the pressure varies considerably in consequence. It should be done in all cases by or under the supervision of the headmaster. A further plan, which should, however, be regarded as supplementary and unofficial, is for teachers to write to, or to make personal calls at the homes of their students. This relation between teachers and students is not to be discouraged, but it does not, of course, obviate the necessity for administrative machinery.

But a great deal of this work in connection with defaulters is rather profitless. The real business of the headmaster and the staff is with the students who attend, and not with those who do not attend. If a student cannot, or will not, attend with fair regularity to all the classes he has joined, the school is better without him. Such a student is a bad example to others of unstable will, a perpetual source of annoyance to the teacher, and an unnecessary expense to the authority. In fact, if the grant did not depend upon attendance, and if the success of a school were not measured so frequently by numbers on the roll, far less trouble would be taken over absentees.

Moreover, a system of "post-carding" is in itself only effective within a limited range. Post-cards and letters make no impression upon some students, except in the few cases in which the parent who desires his boy to attend school receives one. Even then the school secures the unwilling attendance of a somewhat unsatisfactory student. A good many schools recognize the situation and expel students who break their obligations for unsatisfactory reasons, and some require a deposit in addition to the fee from those who have been unsatisfactory in a previous year. Whatever means are adopted it is certain that attendance and homework (*vide infra*) give more trouble than any other aspect of the work at the present time.

TECHNICAL SCHOOL ORGANIZATION AND TEACHING

Before proceeding to consider the arrangement of courses of instruction, it will be desirable to discuss the staff. It is in the constitution and management of the staff of an evening technical school that the most important problems of all arise. In some schools not even the headmaster is employed full-time. Truly, Technical Education is the Cinderella of the educational world—a spare-time job for students, teachers, and local educational authorities, carried on under difficult conditions by a few enthusiasts when the rest of mankind is at leisure.

First as to personnel. There is much to be said for and against the full-time teacher. On the one hand he soon becomes by practice an experienced teacher. He has only one source of income—that is, income earned as a teacher—and his career develops a singleness of purpose that promotes professional zeal. On the other hand, he is liable to get into a groove; the absence of any connection with industrial operations, and the everyday life of the factory and workshop, lead him to take an academic view of Technical Education.

This defect is enhanced by the tendency for young men fresh from the university, who have only spent a limited time—and then in a subordinate position—in the works, to enter the teaching profession. Whatever may be good in the universities, the real need of the Technical Schools is technical teaching having the most direct bearing on the everyday conduct of a business. The school must not lag behind, but must keep well abreast of modern practice.

Part-time teachers, on the other hand, are liable to suffer from the effect of divided interests. They rarely teach more than two evenings a week; they are more or less visitors, and are not actuated to the same extent by professional zeal, and unless they are born teachers, they are liable to initial errors of method, which remain with them to the end of their days. On the other hand, they are in touch with modern practice, and they often treat their subjects with delightful freshness and vigour.

There is still a third class of teacher, who, while not strictly technical, is still an inevitable member of the staff. The Preliminary Technical Course and Practical Mathematics are largely taught by elementary and secondary schoolmasters. In the Preliminary Technical Course these teachers labour under two disadvantages. Firstly, they are only slightly acquainted with the work for which their teaching is a preparation. The Continuation and Technical Schools are co-ordinated, but frequently only in the education office and in the prospectus. All details of the syllabus are not of equal importance, and owing to want of exact knowledge of what is to follow, the teaching may lack perspective. Secondly, a disadvantage common both to the preliminary course teachers and to teachers, *e.g.*, of Practical Mathematics, is want of acquaintance with the daily occupations and technical needs of the students. This is apparent in the choice of examples and illustrations, and generally in the interpretation of the syllabus.

On the other hand, this type of teacher is often trained and invariably experienced. It is spare-time work, but still so far similar to his everyday work that his daily practice helps his evening school work, and *vice versa*.

All this criticism is intended to develop one point—that it would be dangerous to insist on definite types of teachers trained in a particular way for all kinds of technical school work. It is certain that the presence or absence of knowledge or training is secondary to the personal qualities of the men themselves. In the face of any criticism that could be advanced it must be admitted that under cover of night, when most people are enjoying their leisure, work of the highest value, involving extraordinary self-sacrifice, is being carried on by men of widely different training and experience.

The most that can be said is that with younger students, in the earlier years, or when breaking new ground, the professional teacher is the safest; but for older students, in strictly

technical subjects, sound practical experience is a *sine quâ non*.

To proceed now to organization. It will be obvious that this is easier in a school of moderate size than in a large one. The headmaster can keep in close touch with students and teachers. He can enter into the special problems which continually arise in each course. He can keep in touch with preparatory evening schools and with employers, and he holds the future of Technical Education in the district in the hollow of his hand.

But in a large school it is necessary to delegate powers. A somewhat rigid machinery for securing regular attendance is worked from the office, and the teachers are grouped under heads of departments. The departmental system introduces a peculiar difficulty into a course organization, mainly owing to a cross-classification which has grown up. Thus there may be departments of Mathematics, Physics, Chemistry, Engineering, Electrical Engineering, and Building. Apart from a small group of students in pure Science who may require instruction in the departments of Mathematics, Physics, Chemistry, these departments control teaching which belongs to other courses. If each department were self-contained it would be necessary to duplicate laboratories and equipment, and this is an impossibility. Under the circumstances the course system loses its essential unity and appears merely as a group of subjects arranged with some approach to logical order. This difficulty has been recognized, and in some cases departments arrange self-contained courses, with the frequent result that something essential is left out.

Thus a self-contained building course includes graphic statics but no experimental work, because that belongs to another department. There is no need to give other examples; each one can find some within his own experience.

The fact is that a departmental organization is only suitable for the advanced work in a large school, but for this it is essential. It cannot provide the most effective course system

for the earlier years, when closely adherent and broad schemes of study are most desirable.

The character of the course system imposes a new element of responsibility upon the staff. If the course and not the single subject is the unit, the individual teacher is not an independent agent, but a co-operator with limited rights of his own and definite responsibilities to his colleagues. It is each teacher's business to avoid overlapping the work of others engaged in the course, and to utilize their work to the fullest extent. Most of the advantages of the course system in the early stages are lost if the teachers are not generally familiar with the whole instruction which their students are receiving, and prepared to conduct their own teaching in accordance with it.

The proper relation between the constituents is most easily attained in the Preliminary Technical Course, in which it is usual for one teacher to take the whole of the work in the first year. Some local education authorities, however, have a rule that none of their teachers shall undertake work on more than two evenings a week, and the most satisfactory arrangement is then impossible. In the second year's course again it is usual to find one teacher engaged on at least two evenings. But in the first and second year's work at the Technical School the course is frequently in the hands of three teachers. At this stage the student is commencing unfamiliar work, and he needs every advantage that skilful teaching can give him. It is therefore of the utmost importance that the teachers should not only draw up their schemes in considerable detail, but that they should also keep in touch with one another throughout the session. This is a task which will engage the tact and discretion of the headmaster to the fullest extent.

It is strange that there should be such antagonism between scientific and technical teachers. Each tends to regard the other as the most profound ignoramus on every point that really matters. Yet co-operation between them has been

found to be easily possible, and it is a *sine quâ non* if the course system is to be more than a mere name.

Apart from the question of correlation the co-operation of teachers is rendered necessary in order to economize the homework. The exact function of homework will be discussed in the chapter on "The Minor Details of Teaching." It will be sufficient to point out here the need for its regulation and control. If each teacher sets homework how, when, and in what quantity he likes, the results will be uneven. Students invariably express a *penchant* for one subject or for one teacher, and this teacher gets the major portion of the work. It is the headmaster's duty to decide, after consultation with the teachers concerned, upon the amount of homework to be done per week in each constituent part of the course. The total amount is usually such as would require about two and a half to three hours, and which therefore can be done on one evening in the week. This includes as a rule written answers, calculations, and drawing.

It is not always desirable to set homework in each subject of the course every week. The change from one to another of three subjects during an evening involves considerable strain. When a student has done three or four questions in practical mathematics, it is easier for him to do half a dozen more than to do an equivalent amount of work in a new subject. It is a common error to disregard the effect of abrupt jerks upon the mental processes, and to speak glibly of the refreshing influence of change. But once the mind has started working in a certain direction it is less tiring to continue than to change that direction. So, as a general rule, homework in not more than two subjects should be set per week This can be accomplished by arranging a rota at the beginning of the session. If there are three sets of homework, one may be set weekly and the others fortnightly in turn.

It is frequently possible to set homework in one subject that will serve the purpose of two. Thus a question in Mechanics

frequently provides a test of mathematical knowledge, but it does not, of course, serve a double purpose in manipulative practice. A reference to the courses set out in the next chapter will show how homework in one so-called subject serves almost for the course as a whole. In some cases where there is an obstinate tendency to shirk in one class, the homework for the course is set for the week from the office. One set of questions is given, and this serves the purpose of indicating to the student that the course, and not one evening's work, is the unit. The disadvantage of this plan is that the exercises may be set so long beforehand that they have only a vague connection with the system of teaching.

Two other methods are found. One is to set homework in each subject every three weeks in turn It is eminently unsatisfactory. The other is to have all the homework sheets prepared at the beginning of the session These are graphed or printed, and are used year after year. The plan is a relic of a mechanical system of teaching common enough in the eighties, but now, fortunately, nearly extinct.

Whatever methods are adopted, the headmaster will probably meet with difficulties. It will encourage him, therefore, to know that in some schools practically every student does homework.

A new difficulty peculiar to the course system arises in connection with the promotion of students from year to year. In the old days, when the examination determined the amount of grant there was less tendency to admit a student to a class in which he was unlikely to be successful. When the grant came to be assessed in another way a greater tendency arose to admit students to the second stage after a failure or lucky second class in the first stage. During both periods the preponderance of students taking single subjects rendered the question fairly easy of solution in each particular case. But it is now necessary to decide whether a student shall be promoted not

in one, but in three or four subjects, and the problem becomes complicated.

It is obvious that few students make uniform progress in, say, Mathematics, Drawing, and Laboratory Work. Quite apart from natural aptitude there is usually preference for one subject, which, therefore, commands and receives more than its share of time and thought to the disadvantage of the others. This fact makes it undesirable to allow promotion to depend upon an examination which affords too much scope for personal qualities and the element of luck. As a test of a student's fitness to proceed to higher work it is incomplete and uncertain, and it must be supplemented by others which will compensate for its defects.

It is becoming recognized that the whole work of the student at home and in class should be used to decide whether promotion is justified. Marks are allocated for what a student does under the teacher's eye, and for what he does at home. These are added to the marks obtained at any examination for which he may be required to enter, and the sum total determines his fate. The proportion of the maximum necessary to secure safe promotion depends obviously upon the standard of marking. With a reasonable severity fifty per cent. on the whole work is quite satisfactory. But in order to avoid this being reached mainly by excellence in one of the subjects, there should be a minimum in each of them. This is rather more difficult to fix. It ought not to be much lower than that for the whole course, or progress in the weak subject will be seriously hampered.

The chief difficulty arises in mathematics, in which students, equally good in other subjects, show a widely varying capacity. In some schools this is met by arranging for several stages to meet on one evening so that the students can be graded without excessive complication of the time-table. This avoids the necessity of a clever mathematical student being kept back, and enables the weaker ones to enter a class in which the pace is

not too rapid for them. Obviously care has to be taken that every student is obtaining at least that mathematical knowledge and practice which is necessary for adequate progress in other subjects of the course. A higher standard than this may be desirable, but it is not essential.

The character of the examinations for determining promotion is very important, and one to which not much attention has been paid. Their purpose is to ascertain whether the student possesses sufficient knowledge to undertake with advantage the following year's work. A wide choice of questions is clearly undesirable, for in that case a student may qualify and yet be quite incompetent in regard to an essential process or department of knowledge. In some cases it may be desirable to make certain questions compulsory; in others to arrange the paper in sections, and require marks to be obtained in each section.

There is no necessity in such an examination to set questions to ascertain whether everything in the syllabus has been done. Thus a tracing can be submitted in respect of each candidate, and this need not form part of the paper. In few cases will it be desirable for students to submit their note-books, because these will be taken into account in assessing the value of the student's work during the session.

The proportion of marks to be awarded for examination, laboratory work and drawing (which it is assumed are not subject to sessional examination), and homework is important. A scale which has considerable and influential support awards fifty per cent. for the examination, twenty-five per cent. for laboratory work and drawing, and twenty-five per cent. for homework. In all cases some discretion may be allowed, and the border-line papers should be the subject of careful enquiry.

The question of size of classes raises one or two very important problems. If a teacher is merely "lecturing," he likes to have as large a number of students as possible, because large numbers taken at one time are stimulating to him

and apparently economical to the school. But immediately he begins to "teach" he finds that it is not possible for him to get into close mental touch with more than about twenty students during a period of one or one and a half hours. Consequently, when the number of entries exceeds thirty the question of dividing the class has to be considered. It is these "borderline" classes that give rise to the chief difficulty. Unfortunately, classes of fifteen or sixteen are relatively expensive, and there is a tendency to put off the evil day of division as long as possible. The continued existence of a large class reduces the efficiency of instruction, and, as a corollary, the percentage of attendance also.

The most satisfactory plan is definitely to confine admission to each class to the twenty-five best qualified and otherwise most suitable candidates who present themselves by a certain date early in the session. This is neither so severe nor so unjustifiable as appears at first sight. It is quite certain that some of the students will leave by Christmas, and that the greater the competition to enter the class the keener will the successful ones become. It has always been the custom for laboratories to be recognized for a limited number of students working at one time, and there has never been any opposition to this restriction. Once it is recognized that the efficiency of the teaching in the classroom depends upon the number of students whose needs can be met mentally during a lesson period, the soundness of the method must be admitted.

When a class in laboratory work or drawing becomes too large to be effectively dealt with by one teacher, it is a common practice to give the responsible teacher an assistant. The large size of the chemical laboratories and drawing class rooms with which many Technical Schools are provided contributes to this practice. They were constructed of such a size to meet conditions which have since become obsolete, or as a result of views as to extension which have now no foundation in fact. The modern require-

ments in Machine Construction could not have been satisfied by the instruction of large numbers of students in one room under several teachers, and it is now recognized that sound instruction in Chemistry involves such a close association between theoretical and practical work that in the early stages one man must be responsible for both. If a class is large enough to require two teachers, it is large enough to divide, and two teachers each responsible for a section are productive of a higher standard of efficiency than one with an assistant. The only difficulties in the way are mainly historical The establishment of separate classes is the cheapest method in the long run.

If this is accepted in principle it may be well to emphasize the relations which should exist between the two teachers. They may have equal responsibility in the course, or one may be working under the general supervision and direction of the other. It will be obvious that under both arrangements the two men must be equally aware of the work done by all the students, and though their work need not be absolutely the same, the two schemes must be similar in scope and method.

There may be some hesitation in accepting the second arrangement as possessing much advantage over that in which both teachers work in one room But if a man is ever to learn to teach, he must be thrown upon his own responsibility. Merely assisting another never develops his own powers, and never gives him that opportunity and scope which are so necessary for the attainment of skill in any art.

CHAPTER IV

THE ARRANGEMENT OF COURSES OF INSTRUCTION

In order to discuss adequately methods of teaching it will be necessary to keep clearly in view the course as a whole. This chapter, therefore, deals with courses for the more ambitious students in the principal industries. Incidentally, fundamental principles which determine the scope and character of the constituent subjects are outlined. The remarks in Chapter V. will explain why only the first and second years' courses are given in detail.

The Preliminary Technical Course is usually taught in Continuation Schools; but as it is intended to prepare for subsequent technical studies, it is included here. It usually covers two years. In some towns the second-year work is done wholly in the Technical School, and in the larger towns there is often a special Preliminary Course for older students which occupies one session. The ordinary course in the Continuation Schools serves two purposes: firstly, it provides a better foundation for technical studies than the elementary school affords, and, secondly, it keeps the boy mentally fit until he is old enough to follow technical teaching. The last consideration renders it undesirable that boys should be pressed through the course in one year, as is occasionally done. There is a great temptation to hurry a good boy forward, but some acquaintance with materials and workshop processes is a valuable prelude to technical studies.

The problem, then, is to provide a suitable course of instruction for boys fresh from the elementary school who will attend for three nights a week for two years. The lower work must

overlap the upper class-work of the elementary school, because of the early age at which many boys leave school, and the varied standard of attainment presented by them when admitted to the course. The subjects are:

First Year T.	English.
	Practical Mathematics.
	Practical Drawing.
	With Elementary Science or Woodwork optional.
Second Year T.	English.
	Practical Mathematics.
	Practical Drawing.
	Elementary Science, or Woodwork.

The details of the subjects will be dealt with when discussing method in Part III. Here it will suffice to observe that some external examining bodies hold examinations in the subjects of both years. But there is no obligation for students to take the first-year papers. An external examination in the first year has the effect of restricting the freedom of the teacher in developing his subject and a school examination would meet all requirements.

It is generally recommended that Practical Mathematics and Drawing should be taught in close association throughout. This is a thoroughly sound proposal for the first-year course, and for the second-year course where Woodwork is taken as an alternative to Elementary Science. Where the latter subject is included, however, it forms an equally satisfactory subject for numerical treatment.

Practical Drawing in the first year is mainly Elementary Geometry, and the second-year syllabus has a similar content, but it is suggested that more attention should be paid at this stage to projection as a foundation for Machine Drawing and Building Construction. If the Preliminary Course is to perform its proper function it should prepare the ground in such a way

that the technical teacher is free to deal with construction, and has not to teach the elements of projection.

The question as to whether Woodwork or Elementary Science is taken is, in practice, a question of laboratory accommodation. For that reason, too, the second-year course is frequently taken at the Technical School. Few elementary schools are equipped with laboratories, but in many cases admirable use is made of cookery rooms, and even of an ordinary class-room with boards laid across the desks. Wyatt's combined cupboards and benches form a useful substitute for laboratory benches, where there is some available space round the walls of the class-room. Given that suitable accommodation can be found for Elementary Science, there are several reasons for regarding it as the more suitable alternative. There is no industry for which some acquaintance with the elements of Mechanics and Physics is not desirable, or, indeed, essential. Moreover, the claim can be supported from the point of view that every boy in any walk of life should know something of the physical world in which "he lives and moves and has his being." A defect of the other plan is that the existence of a workshop almost invariably implies that manual instruction has been taught in the elementary schools, and it is difficult to arrange a good technical workshop course for boys who have completed a course in manual instruction, and whose practical experience is measured in months.

Sometimes the laboratory accommodation is such that a section only of the students can do Elementary Science; in that case the rest take Woodwork. This leads to the question of classification where there are more students (particularly in the second year) than can be taught in one class. The determining factor is usually standard of attainment, either tested by an examination or estimated by the standard on leaving the elementary schools. But the work of the first year is really of so elementary a character that a boy who cannot undertake it is well nigh hopeless, and another plan which can be followed

in some cases is to divide the students according to occupations. The teacher is then able to draw upon the every-day experiences of the students to a greater extent than if the occupations are very varied. It is perhaps worth noting that the classification may differ markedly from that which is necessary at a later stage. Thus the plumber would be associated with engineers and other metal workers because the similar materials permit of the same or similar examples and illustrations. Of course it may be argued that specialization at this stage is premature, but little weight can be attached to such a contention.[1]

Practically the only courses provided in Continuation Schools are designed for students who will proceed to higher work in technology or commerce. Consequently the standard of preliminary training is lowered by the presence of many who have neither the inclination, the capacity, nor the need, for more advanced teaching. For the type of student in some industries the standard is probably as high as can be expected, but it is extremely low for the ambitious boy who has really profited from elementary school education, and who is engaged in an engineering works or a similar industry.

The first technical course proper to be considered is that for *Mechanical Engineering*. Teachers will be familiar with the controversies that have arisen through the attempt to arrange, on three nights a week, work previously classified under in five or six classes taught, it may be, by as many different men. Very early in the development some subjects had to go, and Practical Plane and Solid Geometry and Theoretical Mechanics disappeared —as separate subjects— from the time-tables of the more progressive schools. Still there remained Practical Mathematics, Machine Drawing, Applied Mechanics, and Heat Engines. On a cursory observation these appeared to contain just what the engineer required, but a closer inspection showed that much of

[1] There is no doubt that wherever possible Science should be taken in place of Woodwork.

the matter contained in the subjects omitted was too valuable to be left out altogether As it is necessary to recast syllabuses, it is just as well to go the whole way, and to effect such a revision that the number of subjects or constituents of a course should correspond as far as possible to the number of eights per week. The tendency, therefore, is to construct the engineering course as follows -

First Year T_3	Practical Mathematics.
	Machine Construction and Drawing
	Experimental Engineering

These subjects are continued throughout the second year T_4

It may be observed that this is apparently a wide departure from the ideal laid down in Part I, which regarded the course as an indivisible whole When a stage is reached, however, in which a special room and special equipment are required, a compromise must be effected The advantage of the scheme will be apparent to those who have to arrange classes to fit accommodation It is obvious that the engineering laboratory will be required for one evening a week for each twenty or twenty-five students in each of the first two years Similar demands will be made for the drawing office and a mathematical class-room. The advantage will also be apparent in arranging the time-table. Instead of filling up a number of one hour or one and a half hour spaces with little parcels of knowledge, each with separate and varying requirements, the units of time are whole evenings, and the units of knowledge are larger sections, each with clear and definite requirements

Now, in regard to scope and character, the course as a whole possesses one definite feature calculations belong to every evening's work. But the main aim on one evening is to increase the students' knowledge of mathematical operations, the main aim on another evening is to increase the students' knowledge of construction and design; and the main aim on the third evening is to familiarize them with mechanical laws, the properties

of materials, and the mechanical advantage and efficiency of machines and prime movers. Every problem is attacked by experiment, by drawing, or by calculation as occasion requires and experience dictates Such a course maintains interest, facilitates correlation, develops initiative and resource, and gives an all-round practical training if it is properly taught in all that the young engineer requires at each stage of his progress, and with no gaps in his scientific equipment.

The establishment of a satisfactory course in *Electrical Engineering* is a more difficult problem The industry itself presents greater variation. On the manufacturing side it is rather highly specialized, and a good many pupils in central generating stations desire instruction Like most other students, the young electrical engineer wishes to jump straight into the technology of his subject, and he does not realize that, using the same tools and largely the same materials and processes as the mechanical engineer, he requires very much the same training. Moreover, as in many schools the number of electrical engineering students is too small to enable separate provision to be made for them, they have to do some, at any rate, of the work in common with mechanical engineering students. The plan most usually adopted is one session Drawing and one session in Experimental Mechanics in the first two years. This gives —

First Year T_3	Practical Mathematics Drawing for Electrical Engineers Experimental Mechanics.	
Second Year T_4	Practical Mathematics Experimental Engineering Electrical Engineering.	Or two nights Electrical Engineering.

The provision of a satisfactory *Building Course* is a still more difficult problem. The Building Trade is more widely distributed than any other, and the numbers in each town are relatively

small. It really consists of a small group of trades working in *different materials*. The carpenter, the bricklayer, the mason, the plumber, the painter, work in close association, and yet each is confined to a particular portion of the whole structure. The young architect and builder require instruction over the whole field, and so also does the young carpenter or mason who desires to become a foreman builder or clerk of works. The introduction of machinery has to some extent degraded the separate crafts, but not so far as in some other industries, and there are still numbers of men who find sufficient scope for their ambition in their own trade, and who require instruction in order to gratify it The students who present themselves at the Technical School therefore exhibit a wide range of ambition and capacity.

The question of a suitable course is complicated by the peculiar relationship between Building Construction as defined by the Board of Education and the syllabuses in Carpentry and Joinery, Brickwork and Masonry, issued by the City and Guilds of London Institute Broadly, the matter of the last three subjects is "assembled" in the syllabus for Building Construction It has usually been considered that Building Construction was most suitable for the more ambitious student, and that combined with Builders' Quantities, Architecture, and some Geometry and Mechanics, it provided all that he required. But in schools which also provide classes in the City and Guilds subjects, advantage is often taken of the course system to include one or more of these in the full course One reason for this is, doubtless, that the Building teacher prefers to keep his students in his own hands entirely, or, at any rate, in his own department. But the inevitable result is to exclude instruction in the Science of Building Materials and the Mechanics of Structures. These subjects are generally included in the lessons on Building Construction, but there is no laboratory practice, no first-hand knowledge obtained by the students themselves,

and they accept the information which is given to them on authority

There is no doubt that the plan of including both City and Guilds Subjects and Building Construction in a course involves an enormous amount of duplication as well as of exclusion of important instruction On that account the City and Guilds subjects will probably be taken in future only in the minor courses referred to below, bearing upon individual trades.

A further matter for discussion is the inclusion or otherwise of Mathematics in a Building Trades Course This has often been attempted, but rarely with more than moderate success. The fact is the calculations of the builder are of a highly specialized character and where they cannot be performed by arithmetic they yield readily to graphical treatment On this account the subject has in many cases been cut out of the Building Course and the more recent tendency is to include calculations of weight quantity, and price in the Building Construction, and in direct association with the details or structures which the student is drawing or measuring Thus as in the case of Machine Construction and Drawing, it is being recognized that the student of Building Construction must have regard to economy as well as to outline and strength

As in the case of Engineering drastic re-arrangement of the scope of subjects is inevitable, and the first two years of a typical Building Course is set out below –

First Year T_3	Geometry of Building Building Construction and Calculations. Science of Building.
Second Year T_4	Geometry and Graphic Statics Building Construction and Calculations Experimental Mechanics.

The subject on the third evening includes in the first year laboratory work on the elementary Chemistry and Physics of

Building materials, ventilation, and the principle of heating and lighting. In the second year the Strength of Materials and Mechanics of Structures will be dealt with in the laboratory.

The scope of the work on the three evenings represents approximately the work of the office, the workshop or yard, and the laboratory, in relation to the industry.

Minor courses for individual trades generally resolve themselves into a theoretical lesson including drawing and any calculations that are desirable on one evening, and workshop practice is the other. The standard of admission to these classes is not insisted upon with the same severity as in the full course, and the students are invariably older. In the separate Building trades there is a tendency for the boy to evade attendance until he can be admitted on the ground of age alone. It would appear that the narrower the aim and the lower the ambition of the student, the greater is the tendency to relinquish technical training altogether rather than to submit to a full three-night course. At the same time there is much to be said for the view that the trade students should attend the classes in Building Construction for a year or two in order that they may appreciate the relation of their own part to the rest of the work.

Courses of instruction in *Chemical Trades* are only possible in districts in which Chemical Industries are largely represented. As a rule, the students are those employed in Works' Laboratories; very few are engaged in the process. The chief industries are Alkali Manufacture, Soap Manufacture, Metallurgy, and Bleaching and Dyeing. Before planning a course of two or three years in duration important considerations merit discussion.

The first is that the student of Chemistry tries to escape Mathematics and Physics. He does not realize that Chemistry is a quantitative science or no science at all, and that every chemical change is interpreted through Physics. Certainly a limited amount of Chemistry can be learnt on the basis of the

Preliminary Technical Course, but it is extremely small. If the student has any desire to proceed to higher work, he cannot withstand the demand that a portion of his time in the earlier years shall be devoted to studies which will render later work easier and more intelligible to him. Unfortunately, the scope of classes in Physics which has hitherto been provided has not been particularly useful to chemists, and the requirements of the course system must again be met by another drastic change. What is wanted is a course of theoretical and practical work in Physics, with special reference to its applications in Chemistry. This would include exercises in specific gravity and density, the measurement of volume of gases, vapour pressure, specific and latent heats, an elementary treatment of the kinetic theory of gases, thermal dissociation, and such an elementary scheme of work in electricity as will render the theory of electrolysis and electrolytic dissociation clear to the student.

Another matter of importance is the scope of the syllabus in Organic Chemistry. Hitherto the first year's work has been confined entirely to the fatty compounds, and has included a discussion of a number of substances which are of comparatively no consequence either from the theoretical or industrial point of view. The benzene and other ring compounds have been relegated entirely to the second stage. The principal industries calling for a knowledge of Organic Chemistry are Soap Manufacture and Dyeing and Coal Tar Colours. The first of these calls for only a limited knowledge of fatty compounds, and is more than fully provided for in the existing plan. Dyeing and Coal Tar Colours, however, demand a knowledge of benzene derivatives, and under the present system a student in these industries has to wait an unnecessarily long time before he learns anything of direct value in his daily work. The needs of both classes of student would be met if the first year's work in Organic Chemistry contained a briefer treatment of fatty compounds and an elementary introduction to benzene and its derivatives.

If the validity of these criticisms is admitted, the chemical trades course may be written down as follows :—

First Year T_3	Practical Mathematics. Inorganic Chemistry (Theory and Practice) Physics (Theory and Practice).
Second Year T_4	Practical Mathematics Inorganic Chemistry Metallurgy, Iron and Steel, or Alkali Manufacture, or Organic Chemistry.

Technological subjects like Soap Manufacturing, Dyeing, and Coal Tar Colours, which involve a knowledge of Organic Chemistry, cannot be undertaken until the third year.

There is no doubt a large number of men engaged in Chemical Industries who would profit by some elementary chemical knowledge Some attempts have been made to meet their needs by admitting them to the Elementary Inorganic Chemistry Class on one evening, and allowing them on a second evening to examine the common materials they use in the Works. These experiments are interesting, and may be developed considerably in the future The chief difficulty is that it requires some technical knowledge and great skill in teaching to give sound instruction in Chemistry in a limited time to students who are distinctly ill-fitted for scientific studies.

In arranging courses for other industries similar methods have to be adopted. No good purpose would be served by attempting to consider these in detail. In general, where an industry offers considerable opportunity for the applications of science and for the employment of scientifically trained men, not fewer than three nights a week are required if satisfactory progress is to be made. In a number of smaller industries, however, in which ambition is limited by the prospects, it is often not possible to secure attendance on more than two evenings. In this case the whole, or a portion, of one evening is spent in the

workshop. Except in Carpentry and Joinery and Painters' and Decorators' work, the expense of providing workshops militates against the provision of adequate courses of this character. While some extension in this direction is hoped for, it must not be allowed to develop at the expense of the fuller and more comprehensive three night scheme. Generally speaking, probably 15 per cent. or 20 per cent. of the students at present attending major courses would be more suitably provided for in minor courses of smaller scope and duration, quite apart from unfavourable conditions of employment, and this proportion varies in different schools. In most cases the provision of minor courses could only be justified by an increase in the number of less ambitious students. But the complaint sometimes made that the instruction is above the requirements of the students is not often justified. The majority of schools are doing the best they can to meet the needs of those students whose character, prospects and numbers justify public expenditure upon them.

CHAPTER V

EXAMINATIONS AND OTHER MATTERS

THE courses of instruction which have been described are only possible where full advantage is taken of the abolition of the Elementary Examinations of the Board of Education

In this system each subject was considered independently, and a rigid adherence to the syllabus gave rise to much unnecessary duplication within the courses The amount required for the examination could rarely be covered if the student were taking the course in his first year, while if he reached it for the first time in the second or third year the examination was too easy.

The sudden abolition of a national test of such widespread influence which has existed for so many years has naturally produced no little consternation, and has brought out rather prominently two national characteristics One of these is the desire of the student to possess some official recognition, however small, of the result of his labours in the form of a certificate, and the other is the peculiar lack of confidence in the teacher. It mattered not that the certificate which used to be awarded by the Science and Art Department bore the somewhat chastening acknowledgment —

"In Nature's infinite book of secrecy a little can I read."

Such certificates were accepted with gratitude, exhibited with pride, framed and hung in a conspicuous position where they would serve as a solace to shattered hopes or a spur to further endeavour. Nor, when the artistic and symbolical sheet gave way to the severe simplicity of a plainly printed card did the value

decrease. Small wonder, then, that a tradition has grown up that a student ought to submit himself annually to an external examiner—an individual robed in mystery and sitting in judgment on the work of the session! Occasionally some prophet arose who denounced the examiner and his works, but generally much was made of those decisions which were favourable, and a discreet silence maintained about those which were not.

Hardly had any one recovered from the announcement that the Elementary Examinations of the Board of Education were to be abolished than new claimants arose for the adulation and deference which had been shown towards an external examining body. The Lancashire and Cheshire Union of Institutes has entered the field, and in an incredibly short space of time has prepared to carry out the work. Moreover strenuous efforts are being made to set up other bodies similar in constitution in different parts of the country.

It is pertinent, therefore, to enquire what are the special disadvantages of external examinations in Technical Schools during the first two years. In these years the technical student is breaking new ground, and he can best learn principles of construction, mechanical laws, the theory of chemical action, through a study of the materials, tools, and processes with which he is most familiar. And certainly for the first session he ought not to proceed far outside the local type of the industry in which he is engaged. This is fundamental. A subject may be introduced as though it were of interest to the Chinese a century ago instead of being of primary importance here and now, but this is not the best way. Any argument on this point which may be necessary will be dealt with in subsequent chapters. For the present it may be taken as one of the simplest axioms of etaching, and therefore of school management and organization.

How, then, is a system of external examinations to take into account all the forms and variety of any one industry in a large area? Is it possible for an examiner—who must not be

engaged in any school within the area—to possess that knowledge which will enable him to foster the right method? Is it likely that any external examiner can avoid influencing the teaching in the schools in such a way that the method and scope assume an undesirable uniformity at this stage? Of course when the general principles of any subject have been learnt they can be applied generally over a wide field, and possibly beyond the first, certainly beyond the second year course the external examiner has an easier task. But it must be emphasized that it is the first-year course which is being especially considered.

The alternative to the external examiner is a school examination conducted with or without external aid. It has been suggested that the teachers should set and mark the papers, and that their standard should be checked by external assessors. Further, it has been proposed that these assessors should be men in actual practice in the industry. The cost might be diminished by neighbouring schools engaging an assessor jointly and contributing towards the expense.

But there is a marked tendency on the part of Local Education Authorities to mistrust their teachers. They do not doubt the marking, but they doubt the ability of the teacher to avoid anticipating the examination at the end of the year, and teaching up to certain typical questions. This danger is probably exaggerated, but the lay mind is not readily convinced. So long as the examinations are of the right type, it is obviously an advantage that the teacher shall have specially prepared for them. The problem is to convey a certain specified amount of knowledge, to develop powers of reasoning, and to achieve a proper degree of skill in certain arts, during the session. If, under the conditions of an examination, without aid from the teacher, the student shows that he has done what was required of him, what more can be desired?

The objection immediately arises that while this may be

granted in regard to a given school, there is nothing to show how the work compares in scope and standard with that in some other school. Obviously this is a serious matter, for there is nothing to prevent a school which is seriously inefficient from remaining inefficient. But have the objectors forgotten that the first, or first and second years alone are under discussion? Is a comparative test required in each year of the course, or will such a test at well marked stages of progress serve the purpose? If so the Board of Education still retain examinations of a standard which is supposed to be suitable for the third year while others of the City and Guilds of London Institute are appropriate for this stage.

The question of an external examination in the lower years turns largely on the liberty of the teacher and liberty unfortunately may be used by him in two ways. It may be used by a teacher to be indolent, to use antiquated methods, and to plough a lonely furrow when he ought to act in co-operation; and it may also be used to develop new methods, to make use of his students' daily environment to give life and tone to his teaching, to open up new fields for cultivation. There are surely means of dealing with the misuse of liberty without inhibiting initiative, resource, and professional zeal! If there is standardizing machinery at the end of the Preliminary Technical Course, that is, on admission to the Technical School, and again at the end of the third year,[1] these would appear to be sufficient safeguards. It is not as though an entirely novel proposal were being made. Several schools gave up the Examinations of the Board of Education some years ago, and many others have introduced subjects for which no external examining body provides a test, and in these cases school examinations conducted by the teachers with or without external aid or assessment have sufficed.

And if the substitution of internal examinations for those

[1] It should be noted, however, that a large number of the smaller Technical Schools can only provide a two-year course beyond T.

by an External Authority causes Local Educational Authorities and Technical Teachers to enquire more closely into the meaning of Technical Education, its relation to industrial organization, and the best methods of school organization and teaching, it will surely more than compensate for any minor disadvantages with which it may be attended.

So much for first and second year courses. It now remains to consider examinations for the third and higher years. In Chapter IV. the writer avoided the discussion of any courses beyond the second year, because the continued existence of the Board of Education examinations, corresponding to the second and higher stages, complicates the arrangement. After the second year the essentials of the course system are of less importance. The student has by this time overcome the difficulties of breaking new ground, he stands less in need of skilful teaching, and he is able to work more or less independently of the teacher. The essential unity of the course system has trained him in the association of ideas and in the correlation of subjects. The mental processes which the teaching was designed to develop are now mental habits, and he is capable, with his wider and better-organized mind-content, of connecting subjects and acquiring knowledge without so much assistance. In fact, the separate subject method is not so disastrous to the progress of the student in the later as in the earlier stages.

This is a fortunate thing. The teachers of higher stages are generally older, more fixed in their methods, and less amenable to the influence of new educational ideas than their younger colleagues. Moreover, the range of the student's work narrows. He leaves the broad shallows, and makes acquaintance with the heights and depths. He begins to specialize.

Let us enquire for a moment what this specialization means. At first glance it might be thought that the early stages involved specialization because of the insistence upon teaching *through* the local industry. But this is only a means to an end—an

avenue by which to attain the broad and far-reaching principles of construction, mechanical laws and generalizations of Physics and Chemistry By the aid of these wide truths the student investigates other matters within his reach and a few outside of it These examples, however, broaden and extend his mind-content, and confirm his knowledge of the laws.

At a later stage another force begins to operate The student's interests are narrowed down by his industrial requirements. He may be in a structural engineering and bridge-building works, and he will desire to concentrate his attention upon the strength of materials and structures He may be in a works in which steam engines are made and he may wish, therefore, to do little but what bears most closely on steam engine design and economy. He may be a builder who specializes in sanitary engineering. In fact, there will always be a tendency for a student to exercise a very strong preference when he reaches his third year

If the Board of Education examinations continue to exercise any marked influence on the work of the schools some specialization will be essential Thus in Engineering there will be classes in Practical Mathematics, Practical Geometry and Graphics, Machine Construction and Drawing, Applied Mechanics (two divisions), and Heat Engines Not one of these six subjects can be dealt with adequately in less than one full evening a week, so that obviously no student can take the whole range.

The situation is still further complicated by the fact that many subjects of the City and Guilds of London Institute correspond to this stage, and one or more of their syllabuses may be followed in lieu of the Board of Education schemes.

The question arises, is it better to continue the course of instruction followed in the first two years, and to have a curriculum suited to each course in each school for the third year, or is it better to follow the schemes of external examining bodies, and to allow options among a number of single subjects? For the ambitious student who aims high there is no doubt

that a further general training, in which the three parallel subjects of the first and second years are continued for another year, is most desirable This would provide an admirable basis for subsequent specialization, and it might, without disadvantage, vary a little in accordance with the demands of different local industrial conditions

As a matter of fact, the character and scope of the work in the third year need not be influenced very largely by external examinations The Board of Education now no longer awards a certificate in a single subject In lieu of this they offer to endorse a course certificate (for which a third year student will be eligible) which contains the whole record of the student during his attendance at the school It contains also a statement of the conditions under which the certificate is awarded, and the results of any examination which he may have taken, whether these are held by the school or by an external body.

It is understood that in approving schemes for these group-course certificates the Board will endeavour to secure a reasonable uniformity of standard, but it is clear that if there is to be much variation in the character of the third year courses, this will be difficult of attainment

The consideration whether any specialization in the third year is necessary or desirable may be left at this stage, for it is practically certain that any difficulties which present themselves here will do so with increased force in the fourth year of the course. By that time students will be about twenty years of age, and they will have before them a clearer view of their position prospects, and educational needs A clever student will probably desire to pass to the Day Technical School or University, and he will desire to concentrate his attention upon those subjects which are prescribed for the examination for any available scholarship. But on the whole this is not the type for which the Evening Technical School exists. If he is to go to a full-time day course it should not, as a rule, be later than the end of the third year

course. The men for whom the school must of necessity provide are those who will continue to be industrially employed in the daytime, and we may briefly consider the kind of work which is desirable for them

Firstly, then, some current notions must be roughly handled. At this stage, for example, Machine Construction and Drawing disappears as a separate subject Applied Mechanics and Heat Engines are now studied with reference to design, or they have no meaning at all and this involves appropriate laboratory work and drawing Similarly Geometry and Graphic Statics becomes merged in Structural Design

Secondly, an engineer may desire to gain some knowledge of Electrical Engineering or of Metallurgy and in both cases, provided that the desire is reasonable and does not arise out of mere caprice, no obstacle should be placed in his way

Thirdly, students engaged in some industry which employs power may desire to acquire some knowledge of the mode of operation, control, and management of machinery and electrical equipment This is a growing necessity, and one for which there are at present very few attempts to provide. One of the most important developments in this direction is the provision of instruction in Engineering for chemists who desire to qualify for the management of works For such students a course consisting of simple descriptions of the chief types of prime movers, their mode of action the transmission of power, the construction of warehouses, sheds, and furnaces, would be of incalculable value in producing sympathetic co-operation between the departments of a works

Fourthly, the schools must recognize that industry has a commercial aspect which cannot be ignored The provision of instruction—preferably from men in actual practice—in workshop costs and accounts, and in specifications and estimates, has become an essential duty of the larger schools. Many students leave the schools with scientific knowledge which

enables them to understand and control the factory or workshop, but with an utterly inadequate knowledge of the relation of construction or manufacture to commercial success. Closely related with these matters is the question of industrial economics. No young man ought to seek responsibility in works management unless he has some knowledge of the economic factors which determine to some extent the successful conduct of manufacture. Apart from what may be termed purely money economics—banking and finance—there are the broader questions of capital and labour, in regard to which a little knowledge and a little sympathy might do a great deal to promote the smooth working of the industrial machine Unfortunately, it is rare to find Economics being presented in any but an abstruse and academic way. It begins with high-sounding phrases and remote generalizations, instead of a simple analysis of the industrial environment of the class.[1] The raw material of abstract science is not embalmed in musty volumes, but ever present in the pulsating life which surrounds the school.

Fifthly, industrial progress is throwing a new responsibility upon Technical Schools. Modern manufacture is becoming more, and not less, dangerous. The use of machinery and electrical power is spreading. Larger quantities of material are being dealt with. Processes are being carried on by machinery which is not sensible of danger, and which keeps on working unless an attendant, with possibly other duties as well, notices that things are not right. New substances and partially understood processes are being introduced. And an increasing proportion of workmen are becoming merely machine minders. All these spell danger to life and limb, and it is becoming increasingly important that the Technical Schools should turn out foremen and managers with a just sense of their responsibility and an accurate knowledge of the precautions

[1] This criticism would hardly apply to J. A. Hobson's "Industrial Economics" which has recently appeared.

which are necessary to protect the life and limb and health of the workpeople.

Sixthly, the school should be prepared to arrange instruction in new methods, new processes, and new groups of knowledge. It ought not to turn out students whose training is necessarily incomplete, and who cannot hope ever to benefit further from attendance. It ought not to be the centre from which merely initial inspiration is drawn, but it should endeavour to become a centre of progress and enlightenment for the whole industrial area which it serves. For this purpose the school should not rely upon its normal staff, but should enlist the service of all the special knowledge and experience it can command.

Obviously any external examining body will have great difficulty in meeting the varied needs of a number of Technical Schools, which are fully alive to their functions and in touch with industrial progress. On the other hand, there is no doubt that internal examinations can only be conducted effectively and economically in large schools with a well-qualified and permanent staff, and even here experience indicates that the labour is extremely heavy. The practice of associating neighbouring schools has not so far been tried, and the greater number are looking to some organized examining body to undertake the work. It remains, therefore, for such examining bodies to break away from tradition and to have regard to those essential details upon which the industrial and economic success of the schools depend.

Note.—Some months ago a meeting of Headmasters of Technical Schools in South Staffordshire was held, and the following resolutions were passed.—

(1) That in the opinion of this Committee the issue of certificates should be decided on marks awarded for:—
- (*a*) Attendance.
- (*b*) Home-Work, or Class Work, or both, and
- (*c*) Examination results.

(2) That external examinations should not be utilised in testing the progress of students during the first two years

of a Technical School Course. (This is not intended to exclude Examination Boards formed by a federation of Schools)

(3) That an Examinations' Board be formed from the Principals and Teachers in Technical Schools. That the duties of the Examinations' Board be.—

(a) To supply assessors for the supervision of Internal Examinations,

(b) To hold examinations at smaller institutions where such institutions so desire

(c) To make recommendations as to the conditions of award of certificates

(4) In order to meet the situation created by Circular 776, issued by the Board of Education, and to carry out the policy therein recommended, it is advisable that an Examinations' Board should be constituted from the Principals and other representatives of the different Technical Institutions, for the purpose of advising and assisting individual institutions in holding internal examinations of a suitable standard for "Course" students in Technical Schools It is therefore suggested that each Local Education Committee be asked to appoint a representative to meet the Advisory Technical Committee at a Joint Conference for the consideration of the whole question

PART III

TEACHING

CHAPTER VI

GENERAL PRINCIPLES

WHATEVER regulations are made by Government Departments, or Public Examining Bodies, or Local Education Authorities, or by individuals who rush into print with theories for the regeneration of the Universe, the final Executive Officer is the teacher The best laid schemes on paper will go astray if they are incorrectly interpreted If the order of teaching is irrational, if the presentation is not clear, if the accuracy of the student's impressions is not constantly checked, if their daily experiences are not utilized so as to show the practical bearing of the work, if the treatment is dull and insipid instead of inspiring and vigorous, the Technical School will fail in large measure to achieve its purpose. The evening student works under so many disadvantages, yet possesses so many good qualities for the common service, that the internal efficiency of the school is of paramount importance. All the preceding portion of the book has been directed towards indicating the conditions which enable teaching to attain the highest efficiency with the least expenditure of effort.

Now there are two things which a student should acquire in a Technical School—one is *Knowledge*, and the other is *Skill*. The first of these is popularly supposed to imply brain-work, and the second hand-work. Thus one generally speaks of a learned physician and a skilful surgeon. But the two are rarely independent of one another, for the workman's skill increases with his knowledge of the properties of materials

and of the processes by which they can be wrought and fashioned. And again, the practice of some art constantly adds to man's knowledge of the world about him. It will be apparent that in all industrial life man is primarily engaged in acquiring and exercising some art such as cutting and jointing timber or stone, filing, machining, or fitting metal, carrying out chemical operations on a large scale, splitting off coal in the largest pieces that can be handled, making rapidly neat, accurate drawings from sketches and so on, and that he comes to the Technical School to learn more about the properties and strengths of materials, the nature of processes, the mode of action and efficiency of machines, than he can learn by mere observation in the factory, the workshop, or the mine Moreover, it will be equally clear that the few hours a week which can be devoted to the Technical School are insignificant in comparison with the forty-eight or fifty four hours in the works, and that the school is not, and cannot be, a competitor with a full-time industrial occupation in developing skill in a practical art. So that the function of the school is to develop that knowledge and initiate that skill which are not nominally developed in practical life, and which are yet necessary in order that the student may become a more efficient unit in the industrial world A very small acquaintance with the hopes and desires of technical students, and with the modern tendencies in industrial organization will show that technical training is generally entered upon in order to escape from manual labour. The student sees quite early in life that knowledge, added to the skill which he obtains in earning his daily bread, will qualify him for a position in which he will obtain higher wages, greater liberty of action, and an enjoyment of the sense of power in controlling those very operations which he is now carrying out under supervision. In the school, therefore, skill is subordinate to knowledge, and it should be confined almost entirely to supplementing rather than duplicating the daily practice of the pupil. Beyond this

conclusion further discussion depends upon the teacher's conception of the nature of knowledge and skill, and the methods of their acquisition It will be convenient to consider knowledge first, and skill in a later chapter

If any man will look back over his past life—not merely his school or college experiences and will recall how he has acquired his knowledge, he will be able to classify the methods of acquisition under the heads of seeing, hearing, tasting, smelling and feeling These senses of sight, hearing, taste, smell and touch have been termed the five gateways of knowledge, because they are the means by which man enters into relation with the world around him If he isolates certain branches of knowledge and considers carefully how he obtained his information he will realize that his knowledge of material things, solids, liquids, gases length volume and weight, and of natural phenomena such as light, heat, and sound has been obtained in the first instance by actual experience His first and most lasting impressions, obtained in babyhood, are from actual contact with material things A Merciful Providence has ordained that this direct contact shall precede the imperfect explanations of the human tongue, and no child is capable of being misled by speech until he shall at least have had an opportunity of getting a little first-hand information about his physical and material surroundings

Very soon—long before school age is reached the child begins to ask questions and receive answers Every answer is turned over in his mind and compared with what he already knows. Those which deal with matters more or less closely related to the facts of experience are understood He believes what he is told, and this belief enters his mind and becomes part of his mental equipment, ready in its turn to receive fresh additions. But answers on matters remote from his experience remain in the mind, if at all, as a mere cloud of words, which wait for their meaning in some further experience or observation.

These considerations show the influence of old knowledge in the assimilation of new Every one knows that the early lessons in a new subject are the most difficult, and when some knowledge has been acquired progress is much more rapid. And here, too, we have the explanation of the difficulty, nay the impossibility, of giving real Technical Education to schoolboys Knowledge, then, is partly experience obtained at first hand, and partly belief obtained from the authority of teachers and text-books Experience furnishes the basis by which belief is made possible Hence

In breaking new ground practical work should come first and the discussion and extension of results should come afterwards

The growth of knowledge by the addition of belief to experience is, however, not the only means, especially at a later stage. The ideas of experience and belief combine to form what may be called a certain mental picture The re-arrangement of these ideas may form a new picture, which, in so far as it aids in the appreciation of new ideas, or prompts to new statements or constructions, or suggests new relations, may be regarded, if not as new knowledge, at any rate as a new form of old knowledge. And not a little of the teacher's business is to assist in this re-arrangement, especially in later years

It is, of course, obvious that a boy acquires many experiences of materials, tools, processes, and structures before he enters the class, and in all cases he has some acquaintance with his physical environment by merely living in it. Hence arises the argument that boys engaged in workshops do not need such adventitious aids to learning as models, specimens, and experiments. In a limited sense this is true For if it were not, the old plan of lecturing would have been a complete failure, and few students would have learnt anything. There is the old story of the mathematician who, during a holiday visit to Germany, was being shown over a university building. Noticing

an unfamiliar machine, he asked what it was, and on being told that it was an air pump, remarked, "Really! I have lectured on the air pump for twenty-five years, but I never saw one before." Nevertheless, we may suppose his lectures had not been entirely unfruitful, and a few terse descriptive sentences or a rough sketch will convey much to the mind of an intelligent student.

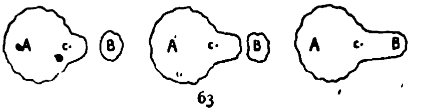
There is, however, an enormous difference in the observational powers of different people. A dozen men may look at one thing and retain a dozen different impressions. Essentials are so mixed with accidentals that the untrained mind fails to separate them, and though each person's mental picture may contain the truth, each has associated with it some little detail which gives it individuality. Now, if the result of this untrained observation or experience is to be used as a model which is to help to explain some new piece of knowledge or mechanical device or chemical process or what not, the old is to be used as the interpreter of the new. And as the interpreters of these twelve students differ among themselves, they will speak each to his own master in his own language, so that the teacher's explanation, however clear and succinct it may be, becomes a veritable babel of tongues.

This connection between the new and the old leads to the familiar educational maxim that—

Teaching should proceed from the more to the less familiar.

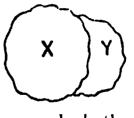
This may be expressed in another way.

Suppose the figure A represents the field of a student's knowledge, and the figure B, a body of knowledge which it is desirable that he should know. Then the teaching should start from some point within his original field of knowledge and extend the field until it includes the figure B, as shown in the diagrams:—



The fundamental fact is that this new knowledge can be absorbed by expansion of the old, but it cannot be pushed in from outside. There must be a starting point C, within the boundary of A, from which initial advances must be made.

Before illustrating this point it will be desirable to extend the idea a little further. If the field of knowledge of an average schoolboy be represented by X, the field of knowledge of a boy who has entered upon an industrial occupation is represented by an addition Y to this figure, so that the field upon which the teacher has to draw for illustration is larger and his starting-point has greater freedom. The figure X will be larger for the boy of better general education, and the figure Y will increase in size with the longer period spent in the workshop. The space Y represents the industrial knowledge—chiefly experience—which the student possesses. For a boy who has been in the works but a short time the figure X will be the best position for the starting point C, in the case of some subjects, but not others. For a man the more recent experiences of the workshop will be found within the added figure Y.



In his case the point C should usually fall within the figure Y, and not within the original figure X.

If no such starting point within either of these figures can be found, then the area must be enlarged, and this is most effectively done by adding *experience* through appropriate practical exercises.

In order to illustrate the method a few examples will now be worked out in full. Supposing a class is commencing the study of heat. Here no one portion of the subject—thermometry, expansion, calorimetry, etc.—can be treated fully without involving one or more of the others. A boy who comes to the preliminary technical class is sure to have some notions of the effects of heat but they will probably be vague.

The first step, therefore, is to examine the knowledge of the class, correct false impressions, consolidate and, where necessary, extend the students' general acquaintance with the subject. According to the best practice, a question asking for a statement of all the effects each boy can think of would be set for homework a fortnight previously but if this has not been done, a series of questions will serve to explore the land

What happens when water is heated? How tested?

What happens when water is cooled?

What happens when water is boiled in a kettle?

What happens when a cold surface is held near the spout of a boiling kettle?

What happens when sulphur, iron, brass, etc, are heated?

What happens when you hold the poker with one end in the fire, or the handle of a teaspoon with the bowl in boiling water or hot tea? And so on

Suitable experiments should be prepared beforehand so as to dispel any ignorance that may be encountered. Two errors have to be avoided. One is to assume that impressions obtained outside this particular lesson or series of lessons are full enough, clear enough, accurate enough for the starting point, and the other is to assume that the students know nothing. The teacher must explore the student's mind, find out what he knows and does not know, and act accordingly. The knowledge may then be systematized by comparing the effects with others which involve permanent alteration, oxidation, and combustion though these names need not be used. This defines the field in the region of the point C more exactly. Then the ideas which are necessary may be summarized as follows --

Heat—

(1) Causes an alteration of temperature

(2) Causes an alteration of size or volume.

(3) Causes an alteration in state

(4) Is transmitted by conduction, convection, and radiation.

The way is now prepared for a study of thermometry and the *aim* of the teaching is established.

This preparation enables the class to enter upon the systematic study of the thermometric scales, the method of determining the fixed points, and so on

The students should perform the following experiments :—

Immerse a thermometer in clear ice and ice containing some salt

Immerse a thermometer in steam from (*a*) boiling water; (*b*) salt solution

Also in the water and the solution.

The results should be stated and briefly discussed. Next the scales of Fahrenheit and Centigrade thermometers should be compared. The students should see that on the Fahrenheit instrument the distance from freezing point to boiling point, the number of divisions or degrees is 180, and for the same range of temperature the number of Centigrade degrees is 100. At all points Fahrenheit and Centigrade readings representing the same temperature are related by the equation $\frac{F-32}{C}=\frac{9}{5}$. The curve can be plotted from this equation, or with a weaker class corresponding readings can be taken experimentally, and the curve plotted.

Up to this point the students have been "prepared" for the new knowledge, they have then acquired the new knowledge, and they have obtained a general statement of the new knowledge in the equation or curve. But the teaching has not yet achieved its purpose

New knowledge is not of much value unless it can be applied. So the next step is to use the equation or curve to find a temperature on one scale when one on the other is given, to find at what temperature the readings are equal, and so on. Incidentally it may be noted that the equation and the graph can be made the starting point for an investigation of the

relationship between them. Thus the attention of the class may be drawn to the form of the equation and the form of the graph, and it may be asked whether any equation of that form will produce a similar graph. A number of equations in x and y are then worked out and the results plotted. In this way the graphical solution of simultaneous equations is practised, and the student learns something of the equation to a straight line.

Before passing to another example it will be well to state again the steps in teaching which were used in the last one.

I.—There was the preparation which resulted in the *aim* being, if not stated, at least understood.

II.—The new knowledge was acquired mainly by experiment, and also by discussion with the teacher.

III.—The knowledge obtained individually by members of the class was brought together, and the several results agreeing, was expressed as a general rule or rules.

IV.—This general rule was applied to particular cases.

It should be noticed that the procedure was from particular to general and back again to particular.

Further, it should be remarked that the limited number of experiments and observations do not prove the rule—they only suggest its *general* character. But in the final stage every application to an individual case which gives a reasonable result is further evidence of validity.

The serious business of reasoning occurs in Step III., where the student has to review his experiments and observations and to formulate his conclusion. Not all experiments or observations are so simple that the bald truth stares the class in the face. In most cases individual results have to be compared and contrasted, the accidentals have to be rejected, and the essentials have to be abstracted, before formulation can take place. Whether the experiments in Step II. are done by the

teacher or the student is often a matter of expediency. There are many experiments from the performance of which the student learns little except how to waste time But there are others in which first-hand knowledge and personal observation are essential, and these should be the students' own work

The main point about the system is that it represents the natural way in which man acquires knowledge First, the slow and laborious accumulation of individual facts; next, the comparison and contrast, the analysis and, classification, then the formulation of a general law, and, lastly, the application of that law to still uninvestigated particular cases

Another illustration may be selected from mechanics

Imagine a class of students who have completed the study of volume and its measurement, and with whom it is now desired to proceed to the study of force The simplest notion of force within the students' experience is weight, or the resistance which has to be exerted to balance a weight They are asked, therefore, how weights are compared Both the beam balance and spring balance will be mentioned, and it really matters very little which is selected first for study If the spring balance is chosen, it leads to a study of elasticity and if the beam balance is chosen, it leads to the notion of the moment of force Anyway, the aim of the teaching having been stated, the experiments are performed, the results discussed and the general conclusion stated. In the case of the spring balance in which the result will be compared with the other elastic bodies, the general conclusion or formulation will be Hook's Law On the other hand, the conclusion from experiments with the beam balance will be the equation of moments. Finally, the application in both cases will consist of the solution of problems, the data of which offer no special difficulty to the students.

It will be of interest now to consider an example in which the starting point C is outside the figure of common knowledge X, and lies in the annulus between this figure and the figure of

industrial knowledge? Consider a class of Building students, attending a class in the science of Building Materials and Structures. The opening is a question as to the nature and use of the material which is placed between the courses of the brick wall of a dwelling about a foot from the ground. It may be assumed that the students have some idea what a damp course is, and what purpose it serves, either from experience on a building or from the class in Building Construction. Hence the answer will be obtained that bricks permit water to soak upwards through them. Then come the questions: Do all building materials soak up water? Do all soak up water to the same extent? What is the peculiar structure which enables water to rise above its ordinary level?

This fixes the aim of the teaching, and the students are prepared for the following experiments and discussion:

1. A dried brick or tile is set on end in a shallow dish of water, and the rise of water is observed.
2. Small blocks of building materials are dried and weighed, soaked in water, wiped and weighed again.
3. Discussion as to the structure which permits this absorption. The nature of porosity—fine channels or tubes between the particles are suggested.
4. The hypothesis is tested by immersing one end of small-bore tubes in water.
5. Other illustrations of capillarity are shown and the name of the phenomenon is given.

Then follows the statement or formulation, and application to other cases—such as lead flashings, effect of porosity of building materials for various purposes, influence of frost, etc., on durability.

The foregoing example is important for two reasons. A cursory examination will reveal the fact that it shows very clearly the relation between pure and applied science—a relation which is very near the actual conditions of practical life. A

closer inspection will reveal the fact that the method is exactly similar to that used in the first two illustrations. The student's attention is claimed from the first by selecting a starting point which appeals to his interests, and the final applications prevent any feeling that the excursion into pure science has been unprofitable.

As a later portion of the book deals in detail with the method of teaching the more important subjects, it will suffice here to emphasize again the importance of the point C. Mechanical and Electrical Engineering and Chemical Industries, for example, are becoming more and more highly specialized, and the technical mind-content of the pupil depends upon the particular objects or materials manufactured, and devices employed in the works in which he is engaged. These are facts which the teacher cannot afford to ignore; a mechanical principle or a chemical reaction can be taught more readily through familiar types than in any other way. The starting point is determined by the character of the local industry, and the knowledge of the student expands outwards in ever widening circles from the more to the less familiar.

The reader who has pondered the foregoing remarks will be prepared for the statement that the unit of teaching is not the individual lesson, but a clearly defined portion of the subject, which may take one or more lesson-periods for its adequate treatment. The idea of a lesson-period as the unit arose from a misconception of the nature of teaching. The teacher felt that it was necessary for him to cover the whole course in, say, thirty lessons. So he adopted the obvious plan of dividing up his subjects into thirty little bits, each of which occupied one lesson-period. Now, if the test of teaching consisted of what the teacher expounded and not what the pupil learned, this method would be admirably suited for the purpose. But the determining factors are the way in which the student acquires knowledge, and the logical structure of the subject. In all subjects it will be found that

the facts, phenomena, and principles arrange themselves naturally in little groups, and within each group there is much closer relationship than between the constituents of two groups. Now, if knowledge is to be of any use at all, it must be organized knowledge, and the relations between facts are equally as important as the facts themselves. There is not a single subject in the whole range of the technical school curriculum which lends itself naturally to an empirical division into thirty lesson-periods, so that to make this the basis of the teaching is to break down the logical relations which are inherent in any body of useful knowledge. Effective teaching demands that this tabloid treatment should be modified in several particulars.

The first step is to ensure that the subject is written out for the whole session in sections, without reference to the amount which can be done on any one evening. The second step is to arrange that the class teaching shall include a general introductory discussion at the commencement of each section, and a final review and summing up of the whole field at the end of it. The so-called lessons which have been outlined in this chapter are not necessarily intended to be completed in one evening. They are intended each to illustrate the treatment of a small organized body of knowledge which is to occupy just so long as is necessary for the students to acquire it. The isolated independent lesson may occasionally contain the whole of the work of a section; then and only then does it constitute a unit of teaching.

The third step is to make an estimate of the number of evenings required for each section, to draw up a list of experiments to be performed by the students and by the teacher, and to provide additional experiments and exercises in drawing or calculation to fill in the time of students who work quickly, and, if necessary, to fill up the time of the whole class when one section has been completed, and it is undesirable to start another on the same evening. It should be noted that the scheme drawn up is a *minimum* scheme to be followed by every student.

Addition to such a scheme is easy. A maximum or ideal scheme which is aimed at but never reached leads to confusion, and is unsatisfactory as a preparation for a subsequent year's work. The clever student can always be restrained with advantage by being given more difficult examples to work out without necessarily encroaching on the next year's syllabus.

It will be apparent that the method which has been outlined is capable of the fullest application to the early stages of subjects in which the student has to arrive at a series of results which can be summarized in each case by a formula or short statement. Thus it is peculiarly suitable for Mathematics and Experimental Science But there are other subjects, like Machine and Building Construction, and Trade subjects generally, in which the final result (Step III) is a body of knowledge about some structure or group of structures, some material or group of materials.

The use of the four-step method ensures that the knowledge shall be acquired in accordance with the natural method of acquisition, and that the final result shall be a fairly clear mental picture of the field which has been explored The fact that, instead of a formula, the student has a picture which cannot be expressed in a formula or simple statement does not invalidate the method. The clearness and accuracy of this picture can be checked and rendered permanent by examples just as well as by a formula.

Whatever subject is being taught, the essential unity of each section should be apparent in the notebooks They should represent clearly in scope and arrangement each little body of knowledge which the student has acquired, but not the amount which the teacher has been able to include in a lesson The notebook is an outward and visible sign of an inward and invisible mental state.

CHAPTER VII

SKILL

ON page 60 attention was drawn to the fact that in the Technical School the acquisition of skill, though subordinate to the acquisition of knowledge, was still necessary. No attempt was made to define the term beyond the implication that it represented facility in some art The arts which most concern the technical teacher are those of speech, writing, drawing, and construction. These are not of equal importance Before the boy reaches the preliminary class he will have had twelve or thirteen years' practice in the use of the mother tongue, and all that the technical teacher can do is to encourage him to develop it in asking for information and in expressing his difficulties

The art of writing lags considerably behind that of speech, and the power to write clearly and succinctly is not often highly developed Every boy will have done some drawing, and many will have had experience in hand-work at school In neither case, however, have these been developed beyond the stage which is necessary for all men, and the special preparation for industrial life is a function of the industry or the Technical School.

Now all arts are similar in two respects- they depend in the first instance upon imitation, and facility is acquired by constant practice In teaching any art it is necessary first to show the student how an operation is performed, and then to let him repeat the process until the desired degree of skill has been acquired.[1]

[1] Creative Art may, for our purpose, be regarded as consisting merely of new combinations of old elements, which have been acquired by imitation and perfected by practice

In regard to the ability to write clear and correct English, the technical teacher will probably say that it is not his business to remedy defects. To a certain extent this is recognized, for the Preliminary Technical Course always includes instruction in composition, as it is called. But a man can only write about what he knows, and in the Technical School he is getting to know more and more with each week of attendance. If the work for which the student is being trained involves not only the knowledge, but also the power to communicate that knowledge to others by speech and writing, it is surely necessary for the technical teacher to see that his students acquire that degree of skill which is necessary for the proper use of their knowledge.

In his control of notebooks, homework, and in his own work on the blackboard, the teacher can do much to secure a gradual improvement in neatness, arrangement, and orderly statement of principles, and in clear and precise descriptions of experiments, machines, structures, and phenomena. A little trouble at the beginning of the session will be remunerative, and will save endless annoyance and disappointment at later stages. The student ought to be able to express himself clearly upon subjects within the limit imposed by the range of study; to small mistakes of grammar too much importance should not be attached. It must be borne in mind that a written statement is more or less a reflection of the condition of the student's mind. No man, whose knowledge is unorganized, confused, chaotic, can write clearly and precisely. To this extent the students' skill in writing depends upon the nature of the teacher's method. No one can go through a series of lessons conducted upon lines which have been laid down without obtaining a well-organized body of knowledge.

The problem of skill in drawing is a little more complicated. Drawing is another means of communicating ideas. It explains the object more satisfactorily than words, and is used where language breaks down. No one can doubt that a skilful writer

can describe a machine or a building in such a way that a person who had seen similar machines or buildings would obtain a pretty good mental picture of the thing described. But this would be a clumsy substitute for the picture itself.

All Technical Drawing resolves itself into two aspects—one is mathematical in the sense that its main purpose is measurement for the purpose of calculation, the other is representative in that its main object is to exhibit space relations. It is with the latter aspect only that these paragraphs deal.

The essential feature of Technical Drawing is that by it the student has to represent an object having length, breadth, and thickness on a sheet of paper in which only length and breadth can be shown in one view. This has to be accomplished according to certain conventions which enable another man to recognize the object which has been drawn. The mental process involved is a comparison of the solid with a flat representation. The first step—which occurs in the Preliminary Technical Course, or earlier—is to explain the conventions, and to show how the drawing is made. After that progress is made in two ways. Rapidity of manipulation of the pencil and instruments is attained by practice alone. Skill in visualizing the object from its flat representation (reading a drawing), and in deciding upon the necessary lines in a drawing, only comes by constantly associating the object with its flat representation. These statements are true whether sketching or scale drawing is the aim. Copying from flat examples—even drawing new views—is of very little value in developing the necessary mental process. Reasonable neatness and accuracy are essential, but the platform upon which these two virtues have been elevated in the past has hidden the real object of the instruction and obscured the true means of attaining the end. Two hours a week is insufficient to secure much rapidity and accuracy in the measured drawing, but much less time than that will enable sketching to reach a fairly high standard of usefulness. For accurate

drawings of complicated pieces of machinery the drawing-office is the only training ground, and thirty-eight or forty hours a week is the most suitable time to devote to them. The school ought not to enter into competition with practical experience under practical conditions, for it can only attempt this by sacrificing more important instruction. In the school, as in the works, drawing is not an end in itself, but a means to an end. It must be recognized that of the three types of student that attend the classes, the average man destined for workshop management will never be required to make complicated drawings, the average man who is in a drawing-office, or who will become a draughtsman, will acquire the necessary rapidity and skill outside of the school; and the brilliant student who is destined to exercise an influence on the progress of industry will employ a draughtsman to do his work for him. Every student who attends an evening school needs practice in sketching real things, if he needs practice in copying from outlines he should not have been admitted. The sketch books frequently used are of little value for teaching sketching. One other point A sketch is made by a practical man to save the time involved in a measured scale drawing, and he avails himself of squared paper for the purpose To use a pair of compasses for drawing a circle is perhaps justifiable, but to use a ruler to draw straight lines in a squared paper notebook is stupid.

The remarks on drawing apply with equal force to workshop skill, except that in few cases is the Technical School concerned at all with it. There is only one place in which it can be acquired with any degree of satisfaction, and that is in the works; but above and beyond this aspect workshop training is not required by students who only attend the school in order to escape the works.

There are, however, a few cases in which the workshop may be a valuable adjunct to the Technical School. Thus a number of engineering students are engaged mostly in repair

work—in the maintenance and repair of plant used in some other industry Such students have often a limited ambition, and they realize that their utility depends upon their being able to execute the work of the smith, the fitter, the turner, the sheet-metal worker, as occasion requires A body of students of this type can be provided for in a school workshop. No very great rapidity or degree of skill can be secured, but they are not likely to be called upon to work in competition with highly skilled men The main thing is that they shall know how to set about a job when the necessity arises Such instruction should cover as wide a range of materials and processes as possible, and in every case something of real value, as a device or machine, should be made That is to say, there is no need to aim at skill by contributing to the scrap-heap To put a piece of metal in a lathe and to practise operations on it until it is reduced to a heap of little helices is industrially immoral. It is better to have an achievement in the form of rough workmanship than to have nothing to show for the labour

There is one marked difference between the training obtained in this way and that obtained in the workshop In the latter the number of hours and the concentration of attention develop a sort of instinct in regard to the properties of materials, which gradually reacts upon and improves skill The limited time in the school workshop renders it necessary to accompany the practical instruction with a series of lessons on the properties of materials, the nature of processes, and the proper function of various tools This workshop science is not an easy subject for which to find a teacher

Another purpose for which an engineering workshop is desirable is for use in connection with the class in machine construction. Owing to the division of labour in a modern engineering works, many students have a very narrow range of experience in regard to those workshop processes which influence construction and design. The question of workshop economy is

one which is of increasing importance, and which is a necessary corrective of the academic character of many of the so-called machine-drawing lessons The teacher will, as a matter of course, be familiar with the kind of work the students are doing and their facilities for seeing other operations; and the existence of a workshop will enable him to give demonstrations from time to time on materials and processes which will greatly enhance the value of his ordinary instruction A few lessons on moulding and casting are particularly desirable, owing to the fact that the foundry is often a separate organization.

In some other trades the workshop takes a more definite place in the teaching. Thus in building, a man in any one of the separate crafts may have work of widely varying character to carry out. Jobs are frequently arising which require special knowledge, and the general training in the joiner's shop or in dwelling-houses is limited in scope. It is usual in City and Guilds of London Institute subjects bearing on this industry to have workshop classes on one evening a week This work is generally associated with the theoretical instruction. To a certain extent it covers the everyday work of the students, but it also extends much further. It deals with knowledge of workshop processes and construction which it would be impossible to obtain by an apprenticeship under most builders, and it aims not so much at the acquisition of skill as at a wider knowledge of construction The exercises depend for their solution upon the skill which the student has previously acquired and is acquiring in full-time industrial employment, and this is characteristic of all the phases of workshop instruction which have been or need be considered.

It is possible that this statement will meet with some opposition. It depends in the main whether we look upon skill merely as the ability to carry out a piece of work, or as the ability to carry it out with such speed and accuracy as to give the achievement a definite value under industrial and commercial

competition. Probably there are a number of tasks in Plumbing and in high-class Joinery in which knowledge and skill in the ordinary sense are required, but in which time is of less consequence In that case the school workshop is of value. But a plumber who has only done lead burning in a school workshop would make a poor show at repairing sulphuric acid chambers in competition with men whose experience and practice can be measured in years.

The relation of workshop training to the instruction required by the artisan ought to make it apparent that the practical and theoretical teaching cannot be in the hands of different teachers if the result is to be satisfactory The writer is credibly informed, however, that this separation does occur in some schools. A university professor may lecture and set an assistant to conduct the laboratory work, but that is no guide to Technical School procedure The explanation in the case of the university is simple, and need not be discussed All that need and, indeed, can be said of such a practice in the Technical School is that if the teaching is to be economical of the students' time and effort the class-work and workshop practice must be in the closest possible association—they must be one and indivisible. Any defect of this kind can only have results which bring Technical Education into disrepute.

There is another kind of skill which it is important for the teacher to understand and to provide for. The early exercises in many mental operations—multiplication, division, logarithms, the slide rule, algebraic factors, etc—involve intellectual effort. The process is at first slow and laborious, the student has to think hard, and it takes a good deal out of him But it is necessary if higher work is to be attempted for these operations to be performed mechanically and almost without requiring serious thought. In this way the mind can be concentrated upon the new work.

Here again we have a case in which practice makes perfect.

Every process of this kind should be reduced as far as possible to subconscious effort by such frequent repetition that its performance becomes a habit. In some cases, therefore, it may be necessary to give purely mechanical exercises to be worked against time. (By a mechanical test is meant one which calls for no thought apart from the particular *operation* of which it is an example.)

But if this is attempted, it should be in the early part of each session only, and its purpose should be to recover ground lost during the summer. When the session has fairly started the work ought to be so arranged that an important process once learned is constantly used. Every good scheme of teaching provides its own practice and its own revision. This aspect of the subject can be carried a little further. The acquisition of skill is essentially the formation of habits, and there are habits of thought just as there are habits of muscular activity. This means that the constant repetition of a mental process—an order of thought, or a form of reasoning—tends in time to dominate and direct the whole mental activity. The method described in Chapter VI. controls the minds of the students to work along lines by which from time immemorial man has acquired his organized knowledge of the world about him. It develops in the truest sense a habit of learning.

This habit is not merely one of acquisition. The method involves classification, comparison, the exercise of judgment, and the use of hypotheses in Step III., and in the hands of a reasonably intelligent teacher it encourages initiative and develops resource in Steps II., III., and IV. The question may be asked—Why, if the method is so rarely followed, is success so generally achieved? The fact is, habits of thought have been developed in some cases before the student reaches the Technical School, and in all cases it is a more or less hereditary attribute of the human mind, which is reinforced and perfected by contact with the material world from infancy onward. The student's mind

therefore works to some extent independently of the teacher's method, and he succeeds in spite of the teacher The contention is that it is the student, after all, who must be most mentally active, and if the teacher so controls the order that it is in harmony with natural mental processes, progress will be easier, sounder, and more rapid.

CHAPTER VIII

THE MINOR DETAILS OF TEACHING

HAVING discussed the general principles which underlie sound instruction, it is now desirable to consider some of the minor details of method, and to examine some of the terms which are in common use.

First and foremost is questioning There are many classes in which the whole of the work is apparently done by the teacher. He lectures, and the students sit passively or take notes. It has been shown that however clear may be his exposition, however skilful he may be in the choice of words, however great may be his judgment in saying all and only that which is necessary, the varying mind-contents of students who are breaking fresh ground will inevitably lead to misunderstanding In the case of an older and more advanced class the danger is not so great, but cases in which a lecture method alone can be adopted with impunity are rare indeed Moreover, they are confined almost entirely to pure description.

Of course the lecturer can ascertain how far his teaching has been understood by setting questions to be answered at home; but in the first place there is the possibility that the answers may be copied from a book, and in the second, it is a cumbrous method for the detection and correction of minor misconceptions

It may be taken, then, that questions should be freely addressed to the class, and that the class should be encouraged to put questions to the teacher. The principles laid down in

the preceding chapter will indicate that this questioning should be organized and of set purpose

At the beginning of the new portion of the subject, the object of questioning is to ascertain the presence or otherwise of the ideas which are necessary for the assimilation of the new knowledge. At no other stage of the teaching is the skill and judgment of the teacher so clearly brought out. Just the necessary ideas and no others are wanted. The so-called "questions on back work" which are often asked at the commencement of a lesson are too frequently useless. So much is asked that the student has only a confused mass of ideas—material and immaterial in his mind and only the sharper ones, who can learn more or less independently of the teacher, are able to grasp readily the new knowledge presented.

Questions are again asked to stimulate the students to devise methods of experimental enquiry. Here, again the student ought not to be told to do experiments without first being led to think *how* they may be done. Even if the method which the student proposes to adopt cannot be followed—and this is generally the case—the mere fact of his mind being set working along these lines helps him to understand more easily the nature of the apparatus and the method of procedure.

If, instead of laboratory work, the new knowledge is to be presented through a drawing exercise, or the examination of a model, the students ought to be quite clear what they want to know and how they are going to find it out, and this again is secured by appropriate questions. When the students have acquired the raw material which is to be worked up into the general truth or truths of Step III, questions are necessary to—

(1) Ascertain whether the students have really understood their results.

(2) Help them to arrive at the general conclusion.

Sometimes the number and nature of individual cases will have been insufficient to enable the correct conclusion to be

drawn. There are too many common features among the results. In this case the teacher must enlarge the knowledge of the class by adding other individual examples so that the common features are reduced to those necessary for the generalization.

Some classes of students object to being questioned by some teachers. It is largely a matter of personality and capacity on the part of the teacher, and habit on the part of the student. If the teacher cannot question, or the students will not answer, the teaching is conducted under a disadvantage. In that case lecturing only remains, and provided the order of treatment obeys to a reasonable extent the principles which have been described, some measure of success may be achieved. But whoever wishes to attain the highest degree of efficiency with elementary students must regard himself as condemned to ask questions as an essential part of his method. He must be a perpetual, but judicious, note of interrogation.

There are several reasons, however, for regarding oral questions and answers as insufficient to satisfy a teacher as to the effectiveness of his method. It is impossible in a large class to test every student on every point—only minor points can be dealt with orally; many students do not think so freely in the presence of others as they do at home, and in comparative quiet, and it is the work done out of class which is so valuable in securing thorough mental assimilation. Merely as a means, then, of testing the progress of each member of the class, homework is necessary, and it derives additional importance from the fact that it ensures a smaller gap between successive lessons in which forgetfulness may operate. Too often homework is set as though its whole function were to assist the teacher in covering the ground for an examination; too often it is looked upon merely as special preparation for an examination, and the work consists largely of answering questions which have been set in previous years. But surely homework

is part and parcel of the method, a portion which, if not systematically and logically connected with the teaching, might almost as well be omitted It is necessary, therefore, to consider the exact function which homework may fulfil.

Firstly, then, suppose the teacher wishes to start a new section of the work at the sixteenth meeting of the class, and that the preparation required for this is certain scattered fragments of experience which every student is supposed to possess, or certain little bits of knowledge which have been acquired in the earlier part of the session In other words, the teacher wants certain well-understood and well-ordered facts in the minds of his pupils which will enable them to grapple successfully with the new problem. The plan he adopts, therefore, is to set examples for homework on the fourteenth evening, the answering of which will produce exactly the state of mind he requires And if the work which is handed in on the fifteenth evening shows that the necessary knowledge is defective, he is able on the sixteenth evening to make the necessary corrections. Without the employment of this method the teacher has to waste time in oral exploration on the sixteenth evening, or take a leap in the dark.

Secondly, the students may be required to examine some facts, compare and contrast, classify and arrange, and draw some conclusion This is work which would normally be carried out in class in Steps II and III, but there are cases in which the presence of the teacher is unnecessary, and it is good for the students to be thrown on their own resources This inspires confidence in the students, and enables the teacher to see whether they are acquiring those habits of thought which it is desirable that they should possess.

Lastly, a general rule having been established, it is necessary to fix it by application to particular cases. This forms a third type of question.

It will be observed that revision has not been included

among the functions of homework. Such revision as is necessary is provided in the step called preparation, and beyond this every properly arranged scheme of teaching provides its own revision. So far, too, the function has been confined to the acquisition of knowledge. The development of skill through homework presents difficulties. Workshop skill is obviously out of the question, but a certain amount of sketching and verbal expression is involved in the knowledge exercises, and these should receive careful attention. It seems doubtful, for reasons which have been already given, and which will be dealt with again in Chapter XII., whether draughtsmanship should form an essential part of home exercises in the earlier years. At the same time much depends upon the course of study and the type of student. In certain trades, such as building, there are many students who experience great difficulty in expressing themselves in language, and it must be remembered that drawing serves much the same purpose as a language. The mere fact, however, that certain students are defective in linguistic expression should rather be an excuse for more careful training in, than for neglect of, this art. And in any case some reasonably well thought out balance should exist between the different forms of skill which appear in home exercises.

There is one widely used method that calls for consideration. That is the plan of requiring drawings unfinished in class to be completed at home. The slow student may easily lose half an hour during the class and another half hour at home. He is thus penalized twice over in an extremely unsatisfactory way. This is particularly the case in a class containing several students who are in engineers' or architects' offices. They set the pace and standard, and many of the other benefits of the instruction are sacrificed to drawing. The presence of students with special facilities for acquiring skill in draughtsmanship outside the class ought to be an excuse for less instead of more drawing in the homework exercises.

Another problem of some consequence is involved in notebooks. It is usual to keep two notebooks for a subject which includes laboratory work one for the theoretical and one for the practical lessons In the early stages, where the theoretical teaching arises out of the practical work in the laboratory, this is undesirable. If the notebook is to represent the knowledge which the student has acquired, and to be of value to him for reference, it should surely contain the links which connect up successive experiments The discussion of results, and the reasons for undertaking further experiment are quite as important as the descriptions of the experiments themselves And if the notebook does not contain these it is rather a hindrance than an aid to study, because it takes up time with relatively unimportant matters A series of detached experiments may be of some value to an advanced student who has acquired the bulk of his knowledge, and is applying it to the solution of further problems, but it cannot be of much value to the beginner who is engaged in building up his knowledge from small beginnings, and whose every step is a further addition to, or systemization of, what he has already gained

At a later stage the theoretical lessons cover a wider field, and the experimental work is a check upon generalization. The theoretical notebook is then of greater importance. Unfortunately, many students find great difficulty in putting down the pith of what they hear shortly and intelligently. In this, no doubt, they are dependent largely on the teacher's method. Clear, precise statement with a proper emphasis on important facts or relations, and a judicious use of the blackboard, certainly facilitate note-taking. The notes taken during the progress of a lesson are generally rough and incomplete, and the earnest and painstaking student naturally wishes to write them out fairly at home; but this imposes an additional burden upon one who is already required to attend on three nights a week and to do homework. Not infrequently writing out notes,

therefore, encroaches upon time which ought to be spent in answering questions. This is disastrous, and its mere possibility demands that theoretical notes should be reduced to the least possible dimensions.

Some teachers prefer to dictate their notes. They save the student the trouble of thinking, and deprive him of valuable practice in expressing his own knowledge in his own language. It is no defence of this method to say that the students cannot take notes. Every one has to learn, and any teacher who evades the difficulty by dictating is simply shirking his share in the responsibility. There are certain cases in which dictation is permissible—with an advanced class. These occur, *e.g.*, when a law or statement is to be dealt with; or when information which depends upon precise statement is being discussed, and which, if it does occur in the text-book, is expressed in vague or inaccurate language. But if the students can be trained to express themselves in their own words first, they should do so, and no effort should be spared to encourage them.

As a matter of fact, the existence of a good text-book renders a lot of note-taking unnecessary. The mere copying out is not in itself of much value, and is far inferior to working out examples. For revision, few students' notebooks are so good as the text-book.

A record of what the student has thought and done is of more value than one of what he has read or heard. Consequently laboratory notebooks call for more careful consideration. Here again it is necessary to speak depreciatingly of the philanthropic spirit which leads the teacher to do the pupil's work for him. The detailed notes which are given out in some schools rob laboratory instruction of most of its value. If the student cannot make his own record after a little showing, he is not worth teaching.

First as to this showing. There are three errors to be guarded against. One is to put down the operations and observations

formally as 1, 2, 3, etc Another is to write the description out in the egotistical and awkward first person singular The third is to begin with a list of apparatus

The laboratory notebook ought to be an exercise in English It ought to prepare the student to write a report in clear, precise, impersonal language. It need not contain instructions to the laboratory boy. It should contain the line of argument which led to the experiment being undertaken, a description of the apparatus and process, and the conclusion It should be a well-articulated whole, and not a discontinuous series

Laboratory work very seldom keeps a student busy during the whole period, and in the case of evening students the notes should be made on the spot. In many cases the home-work forms an application of the results obtained in the laboratory, and though it is usual to require the home exercises to be worked in separate books, the teaching sometimes gains in homogeneity when they are entered in the same one The home-work is as essentially part of the instruction as the theoretical or practical work, and there can be no possible objection to a more or less complete fusion But this depends entirely upon the judgment exhibited in choosing the home exercises

The word "illustration" covers a number of devices used in teaching Broadly, "to illustrate" is to make knowledge clear by means of a picture. This picture may be actually shown to a class, or it may be a mental picture produced in the minds of the pupils

In the first sense, the picture may be a diagram drawn beforehand, a sketch on the blackboard, a lantern slide, an experiment, a mechanical contrivance, a model, an example of holding or using a tool. In the second sense it is an association of ideas, in new or old combination, produced by the teacher talking about certain matters which are either familiar or easily within the grasp of the students. The most important considerations are those which deal with actual pictorial illustration.

There is no doubt that with beginners ready-made wall diagrams should be very sparingly used, especially if they are at all complicated. A complete diagram must be analyzed before it is understood, and this distracts attention, breaks the thread of thought, and imposes a distinct disability upon those whose power of reading a drawing is weak.

A blackboard sketch, growing under the teacher's hand, is apprehended step by step as it grows. The mental process of each student is smooth and steady, it is not subject to jerks which the sudden reference to a complete diagram produces.

The presence, moreover, of a large diagram in a prominent position is liable to attract attention long before it is required, and to interfere with those parts of the lesson which precede and follow its use. A partial recognition of this occurs in one school where, the writer is informed, the diagram is concealed by a curtain during the earlier part of the lesson. When the psychological moment has arrived the teacher gives a signal to his assistant, who unveils the picture with dramatic effect. It is not to be assumed that this method is recommended. The point at issue is the use of wall diagrams for junior students, and the advice tendered is that they should be sparingly employed.

It is usual to criticize the use of lantern slides on the ground that the room has to be darkened, and the students are not then under effective observation. If this has any force the teaching is open to more serious criticism from another point of view, for discipline—not of a military character, but a reasonable orderliness—is a first essential. Generally, however, the use of the lantern itself ensures attention—providing it is not prolonged. There is something fascinating about the brilliant white disc that neither the blackboard nor the linen-backed diagram possesses, and a few slides shown periodically are a stimulus. But this plan shares the disadvantages of wall diagrams when any attempt is made to show complicated drawings to young students.

Hardly less important are those mental pictures which the teacher endeavours to conjure up in the minds of his students by a few questions or by a vivid description. The chief use of this is to help the students to understand the wide range of a law or principle at which they have arrived by the study of a limited number of cases Thus the doctrine of energy has to be clarified and established by reference over a wide field of scientific activity, and each new illustration presented to the class extends and deepens their knowledge Sometimes also illustrations are needed in the form of experiments performed or described in order to broaden the presentation The knowledge that can be gained at first hand is often so small as to render generalization difficult Illustration is here of service in adding to the mind-content, and giving that substantial basis upon which conclusions can rest safely Perhaps the commonest use of illustration and the one which should be most carefully avoided is that which is necessitated by inadequate preparation Here a law, or theory, or description is flung at the class, and the students fail to grasp it owing to the cognate ideas not being prominent in the mind to meet it The class is asked to accept a form of words, and then these words are "explained" by all sorts of illustrations This is teaching backwards The correct order is from the idea to the word, not from the word to the idea The reverse is only justifiable when a statement is to be examined critically as to its meaning and validity, and this is the work of advanced students.

PART IV

NOTES AND ILLUSTRATIONS OF SPECIAL METHOD

CHAPTER IX

THE PRELIMINARY TECHNICAL COURSE

GENERAL REMARKS

THE whole course consists of Practical Mathematics, Practical Drawing, Elementary Science, and English Since Elementary Science demands quantitative or numerical treatment if it is to be taught effectively, it requires from the commencement more Mathematics than is given in the first three months, and the plan of teaching it throughout the first year is a bad one There is no objection, however, to its introduction in the last two months in a modified form, and this overcomes the objection that the whole syllabus in science cannot be covered in one year. It should be noted that the subject is optional in the first year examination, and that nothing therefore is lost by not presenting it

There are some curious notions abroad as to the nature of ractical Mathematics, and the most prevalent is the view that it is merely a scissors and paste edition of pure Mathematics. This view probably arose from the statement that it was intended for students who cannot afford the time for a complete course of the latter subject. This is one of those half-truths that do so much harm Practical Mathematics is intended for those who do not need, and perhaps cannot understand, an abstract subject. It is intended for the average man whose aim is not Mathematics, but some subject to the study of which Mathematics is a useful instrument The word "practical" implies

mainly that a method is used which is adapted to conveying mathematical knowledge to those who want it for some practical purposes. The difference from Pure Mathematics is a difference of attitude rather than of subject.

Let us glance for a moment at the way in which Mathematics arose. In the dim dawn of man's life on the earth he could only have vague notions of his surroundings. As his familiarity with them grew he became able to distinguish similarity between objects, and to be conscious at first of "one" and "more than one." With increasing power of exact comparison he came to add, but this could only be done in connection with each series of objects or interests. After a time he could say how many cattle he possessed, and could state the number of moons to and from his hunting ground. The sense of personal loss involving hardship or increased labour let to subtraction. From this stage he passed to multiplication as a short method of addition, and to division as a short method of subtraction. And in this slow, unconscious way he acquired the habit of dealing with such of his surroundings as were measurable.

So far he had dealt with number, and numbers, as we know, express facts about particular things. They are incapable of expressing general truths, which involve language, but words are rather cumbrous and symbols are used instead. Symbols are, therefore, the shorthand representations of general statements. Perhaps the exact relations of symbols to figures will best be illustrated by an example. The distance traversed by any moving body in unit time is called its velocity. A body moving at the rate of 4 feet a second for 2 seconds covers a total distance of 8 feet, in 3 seconds 12 feet, in 4 seconds 16 feet, and so on. Similarly in 5 seconds a body with a velocity of 2 feet per second will cover 10 feet, of 3 feet per second 15 feet, of 4 feet per second 20 feet. In all cases the method of finding the distance covered when the time is given is to multiply the velocity by the

time. This last sentence is a verbal statement of a general rule, which becomes more useful if expressed in symbols. Thus, if S stands for the total distance, V stands for the velocity, and T for the time, the general truth is represented by $S = V \times T$.

This formula can be used in the solution of other particular cases, and hence the natural order of learning—*From the particular to the general and back again to the particular*—is obeyed.

It may be remarked that the process of thought in building up an equation is a more valuable mental training than the application of the equation to the solution of the problems.

Now the use of symbols for figures is the starting-point of another body of knowledge called Algebra, which for a time runs alongside Arithmetic as a generalized form, and then proceeds beyond into regions of thought where Arithmetic cannot enter. For all practical purposes, however, Algebra should take its place as generalized Arithmetic

If the beginnings of Geometry could be examined in the same way, it would be found that the earliest achievements were in connection with practical needs. Even at a later stage of its development the method of inference from the particular to the general preceded the method of deduction from the general to the particular

Many people seem to think that the new Mathematics consists simply in the removal of certain inconsistencies the clarifying of certain obscure points, and the application to more practical problems. But this is a small portion of the matter. The so-called Practical Mathematics is not a new subject, but a new method—so far as schools are concerned. More correctly, it is the employment of the method by which man from time immemorial has acquired exact knowledge. The deductive method is not rejected, but it is deferred to a later stage for the professional mathematician, and should be relegated, as

Professor Perry once put it, to the Philosophical Faculties of the Universities

Now to a great extent the technical student is similarly placed to primitive man He has limited time; he wants exact knowledge of material things and physical phenomena; and he wants such numerical, algebraic, and geometric forms of expressing this knowledge as will enable him to understand others engaged in the same pursuits. This implies that he must be taught what mathematics he requires through those matters in which he is directly interested It is obvious that if, as has been postulated, Practical Mathematics is the quantitative study of measurable things, which gives precision and exactness to ideas of quantity, size, shape, weight, and physical properties, it must begin by counting, measuring, weighing material things. The particular things then, of which the technical student desires exact knowledge form the basis of his mathematical teaching.

This view emphasizes the point that the particular things through which the mathematics is taught should secure first attention According to the old and still the common view, the order was determined by the kind of mathematical process, and the student obtained, laboriously, a logical structure of mathematical method, with an accumulation of miscellaneous facts about the things in which he was not interested Assuming, therefore, the principle that Practical Mathematics cannot be properly taught except through actual contact with realities, we can proceed to set forth a syllabus of a suggested Preliminary Technical Course in detail

First Year

Section I.—*Measurement* of straight lines with a rule divided into $\frac{1}{32}$ inch Addition and subtraction of lines. Revision of the simple operations with fractions. Scale Drawing as a fractional exercise. Applications to various problems which can be solved by fractions.

SECTION II.—*Decimals* treated in the same way as in Section I A decimal is regarded as a vulgar fraction in which the denominator can be written down from an inspection of the numerator, and is therefore omitted Comparison with percentages which can be regarded as fractions in which the denominator is fixed and therefore need not be written Error of measurement expressed as a fraction, a decimal, and a percentage[1]

SECTION III —*Metric System.* Ratio of inch to centimetre represented graphically Conversion from English to Metric Units

SECTION IV *Distance and time Velocity* Relation expressed by formula S V T, which is regarded merely as a short statement Variable and average velocity with graphical illustrations Diagrams of displacement

Note Up to the end of Section III the object has been two fold

(1) To revise the boy's skill in using fractions and decimals

(2) To deepen his sense of physical magnitudes

Velocity is introduced partly because all boys are interested in moving bodies and partly because the ideas lie at the base of physical science and its application Once introduced, there should hardly ever be a week in which a question is not set upon it

SECTION V *Measurement of curved lines* by experimental methods The ratio of the circumference of a circle to the diameter. Meaning of an approximation in case of incommensurable quantities

The result expressed as a formula—$\frac{c}{d} = \pi$

Speed of wheels, pulleys, and belts.

Note—The measurements of curved lines are preparatory. In ascertaining in different circles how many times the

[1] Some teachers introduce contracted methods of multiplication and division at this stage, but there is a growing body of opinion that they are not worth the trouble, especially where, as in some cases, logarithms are introduced in the second year.

circumference is greater than the diameter, each boy measures up several circles (coffee tins, etc.), and the whole are compared. The conclusion is that $\frac{c}{d}$ = a constant. The real value is now given, and problems set. Among these are such problems as the following —

Draw a circle 3″ diameter Let this represent a pulley to a scale of 1″ 1′.

If this pulley is rotating at 60 revolutions per minute, how many revolutions does it make per hour? per second?

What is the velocity of a point on the rim in feet per minute?

Draw another circle 1″ diameter, with its centre 6″ away from that of the first circle. Let this represent another pulley to the same scale. Draw a belt passing round both pulleys with ruler and compasses

How many feet per minute is the belt moving?

How fast is the rim of the second pulley moving?

How many revolutions per minute is the second pulley making?

With a good class this can be extended so as to establish the formula

$$\frac{N}{N_1} = \frac{D_1}{D},$$

and even problems involving slip can be solved Questions on screws can be added

SECTION VI *Angular measurement. Geometry of the circle* --angles at centre and circumference, angle in a semi-circle, and tangent. Lengths of straight and crossed belts. Construction of inscribed regular polygons from angle at centre.

Note --It is just as well to introduce positive and negative angles straight away. Angular velocity can easily be understood by a good class Circular measure, however, may be deferred

SECTION VII.--*Rectangles* to be drawn on squared paper and rule for area inferred and expressed as A = L × B.

Diagonals. Equality in every respect of triangles so formed to be demonstrated by use of tracing-paper.

The parallelogram and method of finding its area. Formulæ for area of parallelogram—

$$A = B \times H \text{ and for triangle } A = \frac{B \times H}{2}.$$

Equality of area of parallelograms or triangles on same base and between same parallels

The square and square-root by inspection, by factors, and by the ordinary process

Note.—The above section really contains three or four teaching sections, but they are grouped so as to bring out the close connection between the geometrical properties and formulæ. With much of the work the boys ought to be tolerably familiar before they come to the school. The variation of area of triangles on same base with different altitudes, etc., may be plotted

SECTION VIII.—*Algebraic multiplication and factors.* The methods of Section VII applied to the earlier figures of Euclid II. Actual lengths to be taken first, and then symbols to be used, showing the relation between the product and the factors.

Note.—Some practice in algebraic transformation may be given here, if the students appear sufficiently interested. Whether this is necessary depends upon the extent to which symbols have been introduced into the examples following previous sections. A great deal of drill in formal algebra can be dispensed with if the student gradually acquires the habit of dealing with symbols. Multiplication by binomial expressions is sufficient, and long division will not be required for years, if ever at all. Some teachers may desire to give special practice here in simple equations. The absolute necessity for this is subject to the same considerations as algebraic manipulation.

Index notation may be introduced here. It is advisable to work first some examples employing the notation $aaaa$ for a^4, etc. This was the last of a series of notations preceding Newton, and in the original edition of his "Principia" he used the two notations side by side.

SECTION IX.—*Areas of inscribed square, pentagon, hexagon* (constructed according to the method of Section VI), compared

with that of the circle in which they are all inscribed. Hence experimental method of finding the area of a circle. The method of finding the area of an annulus deduced from this and the rule embodied in the formula—

$$(R^2 - r^2)\pi = (R + r)(R - r)\pi.$$

(This is important for engineering students, and so also is ratio of areas.) The area of a circle plotted against radius and against square of radius, and the curves compared.

SECTION X.—*Volume of rectangular solids*—cube, square, rectangular, and triangular prisms, and cylinder. The pyramid, cone, and sphere to be omitted. Cube and cube root of a number (extraction only by factors). Calculations on weight and volume.

SECTION XI.[1]—*Weight considered as a force.* Comparison of weights by spring balance. Extension of a spiral spring and rubber cord. Comparison of curves. Interpretation of the curve for rubber, and examination of the rubber when stretched to ascertain cause. Single, double, and treble rubber cords stretched to the same extent and forces compared. Hence—

$$\text{Stress} = \frac{F}{a}, \qquad \text{Strain} = \frac{L}{l}, \qquad \text{Elasticity} = \frac{\text{Stress}}{\text{Strain}}.$$

SECTION XII.—*Comparison of weights by beam balance.* Moments and parallel forces. Application to practical problems.

Note.—All reference here to the three orders of levers is unnecessary. The chief applications of the principle of moments are in connection with the beams and rotating parts of machines. A few simple examples on the reaction at the points of support will be interesting, and students should understand why a large wheel is an advantage on any draught vehicle.

SECTION XIII.—*Effects of gravitation* explained by reference to parallel forces. Centre of gravity of regular figures found by drawing, and of irregular figures by experiment.

[1] *See* footnote on p. 109.

Note.—This part of the work is not often skilfully treated, and it may be useful to give fuller notes of procedure.

The following questions may be asked:—

(1) In what direction does a body fall when its support is removed?
Why should it fall?
What causes a body to move?
What do you know about the direction of a force and the direction in which a body acted on by the force tends to move?

(2) The vertical is a line drawn through a point exactly over your head, to a point exactly beneath. If it were produced downwards through what point in the earth would it pass?
If the weight of a body be due to a force acting between the earth and the body, will that explain the tendency to fall?

It may now be stated that every particle of matter in the universe is believed to attract every other particle, and that this force decreases with increase of distance between the centres of any two bodies which are being considered.

The result of weighing a body on a spring balance at different points on, or at different elevations above, the earth's surface may next be given. It will be stated that there are two properties—one which alters, and one which does not alter, with position. The former is called weight and the other mass.

If a body has weight w_1 and mass m_1, experience shows that $\frac{w_1}{g} = m_1$, then $w_1 = m_1g$ where g varies according to the distance of the body from the centre of the earth and to the density of the rocks beneath. In the same way, if there is another body of weight w_2 and mass m_2, then at the same place as the first body $\frac{w_2}{g} = m_2$. Comparing w_1 and w_2 we have—

$$\frac{w_1}{w_2} = \frac{m_1g}{m_2g}$$

The g's cancel, and the formula asserts that the weights of two bodies have the same ratio as their masses. As nearly all practical work in Mechanics requires only comparisons, we are justified in measuring masses by the same units as those used for measuring weights.

The latter portion may be deferred for a later period if the class is at all weak.

SECTION XIV. — *Work and its measurement.* Simple problems on lifting weights, etc.

SECOND YEAR

(a) *Practical Mathematics and Science*

In the first-year course drawing has been employed to arrive at mathematical results, and these results have been applied to various problems within the students' range of experience. This numerical treatment of shape, size, and weight, will now be extended to other properties of bodies. Drawing will be taken as a separate subject. For this there are several reasons. If drawing is to be used as a basis for further mathematics, it tends to carry the student beyond his requirements. The kind of drawing which is desirable at this stage, moreover, is more representative than mathematical in character, and should prepare the ground for machine and building construction. On the other hand, science must be treated numerically to be understood fully, and the bulk of the mathematics required can be obtained incidentally from the science lessons. The successive sections are set out and discussed below:—

Section I.—Recall calculations on *weight and volume*.

Meaning of the term density, and calculation of density of regular solids by measuring and weighing solids and liquids. The formula $V_1 d_1 = V d$ in case of U tube.

SECTION II.—How is the *volume of irregularly-shaped solids* determined? Volume by immersion, and calculation of density from this and weight.

SECTION III.—*Flotation*. Immersion of a body of large dimensions suspended by a piece of string in water, and actual experience of buoyant effect. Examination of this. Cylinder and bucket experiment.

Note.—Suitable materials for these experiments are pieces of materials familiar to the student through his

everyday experience A brass weight is not suitable. It is unfair to the weight, and a dull boy is apt to think that he is determining the density of 10 grams or something of the sort.

In the experiments in Section III. it is desirable to use large bodies that can be handled, and upon which the buoyant effect of the water can be felt. The principle of Archimedes should not be mentioned until after the students have understood their results they are then ready for the title and story As many books use the term "specific gravity" in relation to gases, it is well to be precise on this point, and to elicit definitions of—

(a) Density (weight of unit volume).
(b) Relative density (weight of unit volume of the substance compared with the weight of unit volume of some standard substance taken as unity)
(c) Specific Gravity (relative density with water as the standard substance)

Density is a physical quantity, depending on the unity of volume and mass, while specific gravity is a ratio, and therefore a mere number.

SECTION IV.—*Comparison of the properties* of solids, liquids, l gases. Surface tension. Porosity and capillarity. Pressure ow the surface of a liquid

Note. — The work of Section IV. is mainly descriptive, and most of the properties should be "demonstrated" by the teacher. Ordinarily a few weeks either before or after this section would be spent in determining specific gravities by weighing in air and water Beyond the fact that such determinations give admirable practice in weighing, they are of no very great value. The practical man deals less often with the specific gravity of solids than he does with their weight per cubic foot. The density of liquids he obtains by the hydrometer.

The only people who need to determine specific gravities are the mineralogist and chemist, and both of them should have subsequent laboratory training. There is no reason why that should be anticipated, and there is every reason for deferring it until after the student is better acquainted with the forces concerned in the equilibrium of floating bodies.

If the specific gravity of liquids is to be determined

hydrostatically, it will be advisable to deal with balancing columns in a U tube before Hare's apparatus. But neither of these pieces of apparatus should be used until the relation of pressure of liquids to depth has been demonstrated. Otherwise they become mere laboratory tricks

SECTION V.—*Floating bodies* The Hydrometer and its use. Comparison of this method of comparing the volumes of equal weights with the former one of comparing the weights of equal volumes.

Note.- Wooden rods of square section, about 2 cm. thick and 20 cm long, are best for these immersion experiments. They should be varnished, have a paper scale down the side, be weighted at the bottom by boring a hole and pouring in lead, and have a scale pan on the top.

A curve should be drawn showing the volume per unit length This enables the theory to be understood, while the irregular shape of Nicholson's hydrometer (which should be used afterwards) only obscures it The students should answer the following questions —

(*a*) What is the volume of water displaced ?
(*b*) What is the weight of water displaced ?
(*c*) What is the weight of the whole rod and scale pan ?
(*d*) What forces maintain the rod in position ?

Weights are then added to the scale pan and the increase in volume immersed noted.

The rods are next immersed in salt solution, and the results of the two experiments entered up as follows.—

(1) Weight of apparatus weight of water displaced = volume of water displaced density of water (1)[1]

(2) Weight of apparatus - weight of solution displaced = volume of solution density of solution.

As the weight of the apparatus is the same in both cases,

$$\text{Density of solution} \quad \frac{\text{Volume of water displaced}}{\text{Volume of solution displaced}}.$$

SECTION VI --*General properties of air*—weight and elasticity. Barometer, syphon, and pump.

[1] The *c g.s.* units are understood to be used here.

Note.—The weight of air is usually dealt with first. This plan suffers from the disadvantage that all methods of showing that air has weight depend upon its elastic properties. It is therefore better to show generally that air is elastic by reference to a football, bicycle tyre, and by squeezing an indiarubber ball with a hole in it under water.

The pressure of air is explained by analogy with liquids. The employment of a U tube with one limb closed and the other open before proceeding to the straight-tubed barometer is a great help, because many students find difficulty in visualizing the external column of air.

SECTION VII.—*Elasticity of gases.* Boyle's Law. The equation PV = constant, and its curve.

Note.—The students should set out to enquire into the relation between volume and pressure. Half a dozen measurements with a simple piece of apparatus will suffice. The teacher will then give a series of figures for air and, say, coal gas, over a wider range. These are plotted and the curves examined.

The objects of

(*a*) Giving the results over a wider range,

(*b*) Including other gases

are to widen the presentation and thus to enable the students to state the result as a *general gas law* within the reasonable limits of experiment. Generalization upon a narrow basis is invalid, and is to be discouraged.

Inverse variation may be discussed at this stage.

SECTION VIII.—*The effects of heat upon bodies.* Demonstrations on temperature, expansion, change of state, conduction, convection, and radiation.

Note.—No one aspect of the effects of heat upon matter can be approached inductively without involving some idea of other aspects. The simpler effects are therefore demonstrated by the teacher by qualitative experiments. Two kinds of effects will be noticed—temporary and permanent. The latter belong to Chemistry, and their consideration will be reserved.

SECTION IX.—*Measurement of temperature.* Construction of thermometers. Determination of fixed points. Comparison of scales.

Note.—The treatment of this section is worked out in some detail in Chapter VI.

Section X.—*The phenomena of melting and boiling.* Determination of melting and boiling points. Alloys. Vapour pressure and the dew point.

Section XI.—*Expansion of solids.* Is the rate uniform for any one solid? Is it different for different solids? Relation between coefficients of linear, superficial, and cubical expansion treated algebraically.

Note.—A simple apparatus which can be constructed cheaply will enable all the students to work together. This section gives admirable practice in building up equations. Thus the data may be discussed in the following way—

What is the total increase in length?

What is the increase in length per degree?

What increase per degree occurred for each cm. of length?

Then $\frac{\text{increase in length per degree}}{\text{original length}}$ = average co-efficient of expansion.

Suppose a rod of metal is exactly 1 foot long at 0°C, and the coefficient of expansion is a—

What will be the increase in length for 1°, 2°, 3° . . . t°? (a°, $2a$, $3a$ . . . $a\,t$°).

What would be the total increase in length if the rod were 2°, 3°, 4° . . . L feet long? ($L\,a\,t°$).

What is now the total length? ($L + L\,a\,t°$).

Show that this may be written $L\,(1 + a\,t°)$.

Calling the length at 0° L_0, and the length at t°, L_t, we have $L_t = L_0\,(1 + a\,t°)$.

Then after working some examples, discuss in the same way superficial and cubical expansions. Take actual figures to show that the square and higher powers of a may be neglected. Discuss contraction. Compare with algebraic involution and hence infer formula—

$(1 + a)^n = 1 + na$, where a is a very small quantity.

Section XII.—*Expansion of liquids.* Behaviour of water. Relation between density and temperature.

Note.—The simplest way to treat this is to fit a calibrated small bore tube to a 10cc. specific gravity bottle. The latter is filled with water and immersed in a bath. The increase in volume as measured by the rise of water in

capillary tube is plotted on squared paper This gives the apparent expansion. On the same paper, and on the same abscissa, may be plotted the calculated values of the expansion of the vessel The two curves are then added, and the final curve represents the absolute expansion of water No other method brings out so clearly the relation between the apparent and real expansion of the liquid and the expansion of the envelope.

SECTION XIII.—*Expansion of gases* at constant pressure. Increase of pressure at constant volume

Note —There are plenty of simple forms of apparatus The section gives admirable practice in inverse variation

SECTION XIV *Specific heat*

SECTION XV.—*Latent heat.*

It will be observed that the work gives good practice in equations, and especially in direct and indirect variation. Every series of particular cases is followed by examples in which symbols are used, so that the students are continually acquiring facility in elementary algebra One defect is that no chemistry is included. As a general rule, it is not found possible to do more than cover the ground which has been outlined, mainly because of the proportion of slower students who enter the first-year course and hamper the progress of the better students. Where, however, the conditions are favourable, the chemistry of air and the meaning of combustion, at least, should be added.[1]

(b) Practical Drawing

During the first-year course the student will have learnt to use his instruments, and will have become familiar with the method of drawing and the chief properties of the regular figures. The second-year course generally consists of a series of exercises in geometry, accompanied by sketching It is always recommended that drawing should be accompanied by calculation whenever possible.

[1] It is frequently found to be impossible to include Mechanics (pp 102-4) in the first year. The subject is then taken in the second year, and Heat is treated in a more elementary manner.

Note.—The treatment of this section is worked out in some detail in Chapter VI.

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Suppose a rod of metal is exactly 1 foot long at 0°C, and the coefficient of expansion is a—

What will be the increase in length for 1°, 2°, 3° . . . t°? (a°, $2a$, $3a$ . . . $a\,t$°).

What would be the total increase in length if the rod were 2°, 3°, 4° . . . L feet long? (L a t°).

What is now the total length? (L + L a t°).

Show that this may be written L (1 + a t°).

Calling the length at 0° L_0, and the length at t°, L_t, we have $L_t = L_0 (1 + a\,t°)$.

Then after working some examples, discuss in the same way superficial and cubical expansions. Take actual figures to show that the square and higher powers of a may be neglected. Discuss contraction. Compare with algebraic involution and hence infer formula—

$$(1+a)^n = 1 + na,$$ where a is a very small quantity.

SECTION XII.—*Expansion of liquids.* Behaviour of water. Relation between density and temperature.

Note.—The simplest way to treat this is to fit a calibrated small bore tube to a 10cc. specific gravity bottle. The latter is filled with water and immersed in a bath. The increase in volume as measured by the rise of water in

The aim of this order of dealing with an object is to encourage that mental comparison of different parts and dimensions which the skilled draughtsman makes subconsciously. Some teachers prefer to undertake the pictorial sketch first, but for beginners the plan is psychologically unsound.

At this stage it is obvious that great care must be taken to secure accuracy, good arrangement, and neatness. The students must learn to decide for themselves upon the scale to be adopted and the arrangement of the different views upon the paper. They must be under vigorous supervision as to well-sharpened pencils and the correct use of instruments, and a student who persists in handing up slovenly work might as well be expelled from the class.

When a student has drawn an object in plan, elevation, end view, and section he should be asked to indicate the smallest number of views which gives all the dimensions required, and to say which of these are the most useful. A further exercise may then be given in which an object is to be represented by the minimum number of views.

Some isometric projection may be introduced, especially in the case of students engaged in the building trades. The application of the method to mechanical drawing is rather limited.

If the line and plane are included, as in Sections VII and VIII, it is imperative that models should be made. That is to say, the drawing should be cut out and folded along the lines of intersection of plan and elevation, and the line (represented by a thread) or plane fixed in position. This takes a little time, but it ensures that the students really understand the construction.

It is perhaps desirable again to emphasize the importance of drawing from actual objects, and of producing neat, well-arranged work in which the principles of projection are obeyed. The essential aim of the class is to teach drawing, and this must appear in every direction issued by the teacher.

English

Probably no subject offers more variety in method than English in the Preliminary Technical Course. Almost every teacher would, if asked for his opinion, express a different view. In most cases a book is read in class and in a few cases at home also. This may range from a Commercial Reader (dealing with industrial products and processes) to a volume of Dickens. In every case essays are set during the session. These may bear wholly upon the reading, or never include a single topic from the book. A few may deal with topics taken on other nights, but this is rare. They are generally written in class, and occasionally at home. Sometimes a good deal of grammar is included. Not many cases would be found in which attention was paid to English in other subjects of the course.

The object of requiring the subject at all is very clearly to improve the student's ability to express himself, though some would say that it was intended to supply the cultural element in a curriculum that is necessarily narrow and restricted. It will be profitable to consider the former aspect—the improvement of expression—first.

Now this is usually held to be dependent upon two factors—

(*a*) vocabulary,

(*b*) practice in speaking and writing.

Consequently the student reads a book to improve his vocabulary and to furnish models of expression, and writes essays for practice. Assuming that this is true, nearly everything depends on the choice of a suitable book. One containing many colloquialisms, dialogue, or archaic expressions is obviously unsuitable. A book permissible if a broader cultural influence were desired might clearly be unsuitable as a model of style. The examining body that prescribed Browning's *Pied Piper of Hamelin* for the Preliminary

Technical Course certainly did not look to the special book to provide a model for a technical report!

But the statement as to the question of vocabulary and style is really only a half-truth. Expression postulates knowledge which can be expressed. Words without ideas behind them are pedagogical skeletons—useless for every purpose in life. Moreover, knowledge which is not systematic, well-arranged, organized, cannot be expressed clearly and succinctly. So that the first essential of expression is a well-stocked mind, and the second is practice in expressing what the student knows. Any book which is of such interest to the students that they will readily think, talk, write about its contents forms an admirable medium for securing orderliness of thought and fluency of speech and writing. And for this purpose none of the other subjects upon which the student is engaged can be rejected It is imperative that the whole of the work that the student does should contribute its quota.

Just a word as to securing orderliness of thinking. It is first necessary that the student should be sufficiently acquainted with the topic to think at all. Imperfectly digested knowledge, introduced at the beginning of a lesson for the purpose of an essay, is practically useless. And in any case a topic involving many points is not suitable for the early part of the session. If, however, answers to questions are asked for, the student is not worried by the "form" in which the answer is to be given, and he concentrates all his attention on the subject, as he ought to do. Simple questions involving only one idea are replaced by more complex questions involving two or more ideas, and these give place in turn to questions which require "essay" answers If in the result the arrangement is bad, it should be discussed in class, a plan drawn up, and the essays rewritten. But it is most undesirable to draw up a plan for an essay which involves wholly new knowledge. Any attempt to systematize knowledge

before the exact defects of system are known is a leap in the dark.

So much for expression The attempt to introduce a broader culture into the course by a book of real literary value is outside of the main question, and stands or falls by the teacher's ability to deal with the book in the right spirit If he can do so, well and good. If he cannot, the attempt is a waste of time.[1]

The question as to whether grammar should be included is one of very great difficulty. It is certain that mistakes of speech and writing cannot be corrected intelligently without some reference to the laws and principles by which language is governed. At the same time, most people speak according to habit, and not according to grammar, and it is doubtful whether the "habits" of daily life can be affected by a few minutes' instruction twenty-five times a year. It is something to make a man intelligent and intelligible. To make him grammatical also is a task for the gods!

[1] The writer has no desire to belittle the importance of literary study for industrial students, or to deny the possibility of its inclusion in the Preliminary Technical Course But he has thought it desirable to emphasize the minimum requirements, and to indicate how these may be secured, without making too great a demand upon the teacher's literary taste and discernment.

CHAPTER X

MATHEMATICS

THE character of the work in the Preliminary Technical Course has already been described. If the subject has been skilfully taught, the pupil will be able to solve elementary examples in mensuration, and he will have acquired some facility in the use of simple equations. Further, he may—in fact, he ought to—be able to solve problems involving the sine, cosine, and tangent, and to use a set of tables. Of formal algebra he will know very little, and of deductive geometry nothing at all. Still, the knowledge outlined is—provided it is sound—very nearly sufficient to carry him through the first year's work at a Technical School. A very slight extension, in any case, would be ample.

But, notwithstanding, it is customary to attempt a scheme which goes very much further, and it will be well to show in what way this is undesirable. It may first be observed that the change from the type and character of the instruction in a Continuation School to that in a Technical School is a severe strain. The student plunges directly into the study of technical subjects under teachers who are more or less specialists, and who frequently lack that skill which is so necessary when new ground is being broken. He leaves a school in which the teachers are experienced in dealing with beginners for one in which they are not; and he becomes a member of a class of selected minds. For in every co-ordinated system of schools in which attendance is voluntary the weaker students fall out each year, and the general level of ability and perseverance rises. The student

who enters a Technical School enters upon a life that is more strenuous, and into a competition that is keener, than those to which he has been accustomed. During the first year many find the pace too hot for them. So long as they remain they derive benefit at least from the technical subjects, and on account of the presence of both classes of student it is unwise to make the standard in mathematics *unnecessarily* high. A heavy fall in attendance in the first year is more likely to be due to extravagant notions of the importance of mathematics at this stage than to any other cause.

Mathematical education in this country is in a transition stage, and opinion is so divided that it is difficult to discuss matter and method without entering into polemics. One principle alone may be regarded as generally accepted—that a man who requires mathematics only as an aid to the study of some applied science need not go through a complete systematic study of mathematics. But beyond this complications arise. Some consider that the principle is satisfied if the student learns certain rules by rote, and performs mathematical processes mechanically. Others believe that the principle merely sanctions omissions, and that it involves essentially the ordinary rigour of mathematical proof. Between these two extremes will be found every error that is committed in mathematical teaching. Another way of stating the principle is to say that so long as a student can understand the mathematical operations in the technical books he is required to read, and can solve the problems which are likely to arise in his daily work, his need is satisfied. This, perhaps, brings out more clearly the fact that the technical student has no responsibility in regard to the development of mathematical science or the establishment of its laws, but that he must understand some of its methods and be acquainted with certain of their results.

The difficulty in practice in acquiring this knowledge and skill arises from the fact that mathematical science itself is

established by deductive methods. Historically, mathematics commenced as a practical art, and many of its truths were apprehended experimentally or intuitively and used for practical purposes long before they yielded to logical proof. Similarly, intelligent use can be made of results by those to whom the proof would be unintelligible. In fact the teacher must distinguish between the function of a proof in the classroom and in the establishment of a science. In the former its main purpose is to convince the student that some relation is true, so that he may use it with confidence. In the latter the purpose is to convince leaders of thought that the relation is true. The student must make use of relations, the proof of which he could not understand, and to give him a proof which, while intelligible to mathematicians, is unintelligible to him is a farce—but one which is frequently played.

The word "proof" has been used here because any argument which carries conviction is commonly said to "prove the point." In order to avoid confusion, it may be well to set out the three methods for securing conviction which are available for the mathematical teacher. These are—

(1) Experimental

(2) Intuitive.

(3) Logical or scientific.

The experimental method is a proof within the limits of manipulative or instrumental accuracy of a particular case. It does not furnish a proof in the sense understood by mathematicians, but is generally simple, practical, and adequate to secure conviction.

If a number of similar experiments are performed either by one student or by distribution among the class, contemplation of the results often suggests the existence of a general law, and the minds of the students grasp the truth by "intuition." This, again, is not a proof in a mathematical sense, but it convinces the student, and the method by which it was reached

impresses the truth on his mind. Moreover, it encourages hypotheses and develops the experimental habit.

The logical or scientific method suffers from the disadvantage that many minds have great difficulty in realizing a universal statement. So long as particular cases are first presented for their consideration, they may be able to go a long way towards the conception of a universal truth, but this mental attitude has to be approached by easy stages.

It is now possible to advance a second principle—the mathematics specially suitable for technical students is not described exactly by the statement that it is a shortened course. It is a selection of mathematical methods and truths studied mainly by experiment and intuition, and only sparingly in the early stages by logical methods of investigation.

This principle neither encourages pseudo-scientific methods nor excludes the development of a more purely intellectual interest. The teacher is free to use his judgment in the employment of more rigorous methods of proof, provided always that they are within the comprehension of his class. But he will always be limited by the fact that some proofs involve preliminary excursions into pure mathematics which the more pressing needs of his students would not justify. He cannot build up a comprehensive structure of mathematical science. That is the business of the mathematicians. At the same time, he ought to make quite clear to his students the nature and value of the methods they use.

At the back of the two principles which have been enunciated is the idea that for the purpose in view mathematics is an art, to be practised in close association with the other subjects of instruction. This does not mean that it should be taught as a separate subject and then applied to other subjects, but that it should be derived from a quantitative study of these subjects. Just as in the dawn of civilization mathematical ideas arose from man's study of his environment, so should the student

develop the habit of dealing with his mechanics, or whatever it may be, quantitatively.

To put the matter in another way, the use of the experimental and intuitive method involves first the study of concrete particular cases. These may just as well be the constructions in geometry or the relations in mechanics, as examples drawn from anywhere for no apparent reason. This plan does not give a narrow training, as is sometimes urged, because however the process arises or the relation appears, it can be used in solving miscellaneous examples of a similar type. Similarly, the objection that mathematics if studied incidentally in connection with mechanics would be in an illogical order does not hold. For if this were so a separate class in mathematics would not help a student to solve problems of more than a certain difficulty in mechanics. If the objection has any weight in a particular case, the syllabus in mechanics needs to be recast.

A criticism that has, at first sight only, more force is that the students' mathematical knowledge would be unsystematic. But this is really of no consequence. His mind ought not to be organized in three compartments—one for each night of attendance, and his mental processes do not consist of the superposition of a portion of the contents of one department upon a portion of the contents of another! A well organized mind-content is organized as a whole—there should be quite as close association between a mathematical relation and the physical relation which it may represent as between that mathematical relation and others which are logically connected with it. The advocates of a separate and systematic study of mathematics have only the mind-content of a mathematician in view. What is needed by the student is not so much a knowledge of mathematics as a mathematical knowledge of his technical subject. Ideas about mathematics are of less importance than mathematical ideas; for the latter will prompt a man habitually to deal quantitatively, and therefore exactly, with any subject

that lends itself to quantitative treatment. The ideal arrangement, therefore, is one in which mathematics is not treated as a separate subject.

But however sound this doctrine may be, there will be many cases for many years in which mathematics is not only taught in a separate class, but also under a separate teacher. There can, however, be no possible objection to the use of data which are obtained in other subjects of instruction, and what is needed more particularly is the employment of these as the starting-points in the mathematical teaching. As in other subjects, these points should be within the circle of experience and interest. Perhaps in no other subject is the starting-point so generally remote from interest and experience, and this is certainly one of the reasons why mathematics is often found so difficult. A golden rule of teaching mathematics is to break new ground by considering an interesting and practical problem, and thus to lead the students to feel the importance of forging a new weapon.

It remains now to indicate briefly the scope of a First-Year Course of Practical Mathematics, assuming a knowledge of the Preliminary Course. In view of what has been written this cannot be done in a very satisfactory way, because the mathematics should depend on other subjects. Still, at this stage the subject is more generally associated with geometry, and this subject will be taken as the basis. The scheme should not be taken, however, as indicating much more than the scope and general arrangement of the teaching.

I.—*Length*. Use of Vernier, sliding and screw callipers, and spherometer. Limits of accuracy in drawing in the laboratory and in the workshop. Averages and approximations. Problems involving fractions, decimals, and percentages.

Note.—The object here is to revise the conception of units, to extend practice in measurement, and to render the knowledge of methods and limitations more exact. The

use of a small lens for reading small distances may be introduced. If this is mounted in a cork with a piece of cardboard having a hole and a vertical thread across it, some accurate results can be obtained with an ordinary ruler.

The kind of problems may vary with the students. Those in engineering may deal with the sizes of bolts, nuts, rivets, metal plates, and there is a wide range of calculations suitable for students of chemistry and physics. Any of the Preliminary Technical Course work may be drawn upon, but if problems are set outside this, care must be taken that the data are understood

II.—*Logarithms.*

Note.—The use of very large and very small numbers in the first section will have shown the desirability of a simple nomenclature, and the index notation may be explained and used. After the student has become familiar with this, he is introduced to logarithms—first by plotting 10, 10^2, and 10^3 on squared paper. When the meaning is clear, the rest is a matter of drill.

It is of the utmost importance that all work involving logarithms should be neatly arranged, and an uncompromising severity at this stage will save much time and trouble later. No slip-shod or untidy work should be tolerated for a moment. During the remainder of the course logarithms should be used regularly and systematically.

III.—*Angular measurement.* The circular measure of an angle. Angular velocity. Other properties of an angle—tangent, sine, and cosine. Projection of a line on a plane by drawing and trigonometry.

Note.—The student ought to be sufficiently familiar with the measurement of angles in degrees. The radian often presents a difficulty, especially when it is taught from a book. At this—and, indeed, at all stages of the work—the student should have his instruments at hand, and geometrical constructions should precede theoretical discussion.

Thus, when a student has drawn half-a-dozen circles of different sizes, and has marked off on each circumference a distance equal to the radius, he will readily conclude that the radian is independent of the length of the radius

It is probable that the students are already familiar with the sine, cosine, and tangent, which will most likely have been introduced in connection with the right-angled triangle. It is therefore desirable that they should learn to regard these relations as pertaining to the angle itself.

It is assumed that the constancy of the ratio of the sides of similar triangles has been shown in the Preliminary Course. If this is found to have been forgotten, it must of course be dealt with here.

IV.—*Mensuration of regular figures.* Revision and extension with use of trigonometry. Algebraic expressions involving second powers and their factors.

Note.—The methods of constructing and calculating the areas of most of the regular figures will be known. This revision gives some practice in trigonometry, and enables more difficult examples than those of the Preliminary Course to be solved.

The introduction of algebra at this stage requires some explanation. Practice in the manipulation of symbols is necessary somewhere, and the usual plan is to fling it at the student without reason. The essence of teaching is to get the student to feel the necessity for the next step. In this case it is natural to proceed from particular cases of area to general statements, and this introduces expressions involving the first and second powers. The student enters upon factors through concrete illustrations. Compare the remarks in the early part of Chapter IX.

V.—*Similar triangles.* Ratio and proportion. Areas of similar figures. Reduction and enlargement. Variation.

Note.—In several books ratio and proportion are dealt with algebraically and then applied to the study of similar figures. The geometrical method is preferable. As a matter of fact, the idea of ratio is involved in fractions, and proportion is best understood as an equality of two ratios. Some mathematical teachers object to this very strongly, but it is not easy to see where the validity of the objection lies. The difference is mainly one of expression, and the ideas are precisely the same.

Variation is appropriate here, because in its simplest

form it is a statement of the relation between two quantities whose ratio or product is constant.

VI.[1]—*Solids.* Revision and extension Development of pyramid and cone. The sphere Volume and weight. Algebraic expressions involving the cube and higher powers and their factors.

Note — In this section again there is a manifest advantage in accurate drawing to precede the new rules in mensuration.

The development of the rectangular triangular, and hexagonal prisms and of the cylinder, should be familiar, and will probably not need to be done again That of the pyramid cone and sphere will be new The pyramid should be treated trigonometrically probably a hipped roof or the pyramidal top of a square gate post will furnish a good example In all cases some actual object which has acquired interest from its relation to industrial operations is better than a mere geometrical model.

Thus the surface and contents of tanks in the form of pyramids and cones, and conical or pyramidal hoppers, provide admirable exercises Another suitable subject is a cylindrical tank with hemispherical ends, and the amount of metal sheeting required for a domed roof

The introduction of further algebra at this stage depends upon principles which have already been discussed.

VII.—*Equations and Graphs.* The co-ordinates of a point. The equation of a straight line Interpretation of the constants and their effect on the line. Solution of simultaneous equations Treatment of experimental results

Note —This section is intended to systematize the students' knowledge of equations and graphs, and to serve as an introduction to co-ordinate geometry In order to secure dexterity in plotting, and to familiarize the students with the four angles, some practice in plotting the position of points should be given Reference should then be made to variation (Section V), and it should be shown that the graph exhibits the *continuous* variation of one quantity with another.

Graphs of this kind should be sharply distinguished

[1] This Section may precede section V. in some cases

from those which represent statistics and prices. The essential characteristics of the equation of a straight line should be emphasized by comparison with the graphs of the equations pv=constant, and ax^2=by. In dealing with experimental results the ability to interpret the curve is of prime importance.

Experience shows that the scheme set out in the preceding pages is liable to be misunderstood It will therefore be an advantage to state each section in terms of the mathematical results and processes studied —

(1) Fractions, Decimals, and Percentages
(2) Indices and Logarithms
(3) Angles and their properties
(4) Simple Involution and Algebraic Factors
(5) Ratio, Proportion, and Variation
(6) Harder Involution and Factors
(7) Simple Co-ordinate Geometry of the straight line

Before leaving this subject, it is desirable to emphasize, even at the risk of repetition, one principle That is the way in which each lesson is introduced Referring to Chapter VI., the starting-point must be within the range of the student's interest and knowledge. It may be something which arose in a previous section or something which has arisen in classes held on other evenings in the week. The former method has the advantage that it tends to make the subject a better articulated whole, and the second has the merit of emphasizing the essential unity of the course In the first year, when the mathematics is subsidiary, when the student is, in fact, learning mathematics largely through engineering or physics, the latter method should be used wherever possible.

In small schools it frequently occurs that each class in mathematics is attended by students who belong to two or three courses. Clearly the second plan is then impossible. But it does not follow that the subject need be wholly divorced from

the main interests of the class. Occasionally the fear of making the subject too narrow or technical leads to applications which are of no interest or value to any of the students.

If the subject is self-contained so far as the starting-point is concerned, it need not be so in regard to application, and though the teacher has to introduce each section through material which is familiar to *all*, he should keep in mind the various interests represented, and should be prepared to apply the mathematics to the constituent subjects of all the courses of which the mathematics forms a part. If the class is so mixed that it cannot be divided into at most three groups, then the best conditions for efficient teaching are absent.

The second-year course need not be discussed in detail, but an outline syllabus may be useful.

I.—*Indices and logs.*

(*a*) Index notation revised. Simplification of expressions containing surds and indices.

(*b*) Common logs. Slide rule. Tables. Rule of proportional differences. Change of base. Natural logs.

II.—*Trigonometry.* Extension to include the formulæ:—

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}; \qquad b^2 = c^2 + a^2 - 2\,ac\cos B;$$

$$\Delta = \tfrac{1}{2}\,ac\sin B$$

Application to the projection of a line on two co-ordinate planes, and to the triangle of forces.

Vector notation applied to velocities and forces.

III.—*Linear equations and graphs.* Revision of previous year's work.

IV.—*Quadratic equations and graphs.* Graphs of $s = \frac{1}{2}gt^2$, and $s = vt \pm \frac{1}{2}gt^2$.

Graphs of $y = ax^2$ and $y = ax^2 + bx + c$. The parabola. Maxima and minima. Solution of quadratics graphically and analytically.

The equation to a circle.

V.—*Inverse variation*. The equation pv = constant and its graph. The rectangular hyperbola.

The equation pv^n = constant and its graph.

VI. *Equations*. Miscellaneous equations which are more readily solved by analytical methods.

In both years the introduction of rigorous scientific proofs is entirely within the teacher's discretion. He should bear in mind, however, that a proof which satisfied him is of no value to his students unless they understand it. As they are not mathematicians, there is no obligation for them to go out of their way to establish mathematical truths. It is their business to try to understand such truths, and it is the teacher's business to present his subjects in such a way that they can understand them. It is obvious that he should avoid, as far as possible, offering any statement as a truth which he himself could not establish if occasion required. This is the minimum requirement of the trust reposed in him.

CHAPTER XI

EXPERIMENTAL SUBJECTS

In dealing with any experimental science it is first necessary to consider what is the precise function which laboratory work plays in teaching. So far as the earlier stages are concerned the question has been answered in Chapter VI. It is there shown that practical work is necessary in a new subject to create the nucleus of experience around which can be built up the wider area of belief. The student must learn at first hand something of the properties of matter, the mode of action of machines, the nature of physical phenomena and chemical change, and the meaning of experiment before he can appreciate the vast stores of knowledge that have accumulated since man emerged from the obscurity of the cave. This need of personal observation and experience has been felt even by men who could not be charged with lack of imagination. It is recorded of Michael Faraday that he rarely entered upon any research until he had repeated the more important experiments of those who had preceded him.

Now there are some students so constituted mentally that they can learn almost as much by merely seeing an experiment performed as they can by personal execution. In the old days the student who attended classes in physics or mechanics or chemistry might see many experiments performed, though he was rarely allowed to attempt them himself. Still he learnt a good deal. In recent years the pendulum has swung in the opposite direction, until it is considered necessary that nearly

every experiment should be carried out by the students individually. In this way a great deal of time is wasted upon the performance of experiments which teach very little.

Unfortunately the rise in importance of laboratory work and the concentration upon experiments which give quantitative results has killed the more showy lecture experiment which, if it did not convey much exact knowledge, at least attracted the student, stimulated his interest, and spurred him to activity. On the other hand, the laboratory has tended to become more quantitative and less inspiring in character.

The latter result was probably inevitable, for when laboratory exercises are introduced exact numerical statements are indispensable in order to build up results; and measurement, rather than qualitative observation, becomes of first importance. But measurement is not so much an end in itself as a means to an end, and the newer method depends less upon the intrinsic interest of the practical work than upon the joy of intellectual acquisition to which it leads. For it cannot be denied that the entry of a new truth into the mind produces a feeling of pleasure, and serves as a stimulus to further effort, which is at least equal to that produced by more showy experiments. Any one who doubts this has only to look at the faces of the students when a point hitherto obscure has suddenly become intelligible to them. In fact, their facial expression is an excellent indicator of the effectiveness of the teaching.

The principle enunciated in Chapter VI. that experimental work should precede discussion in the early stages is not very generally recognized. The laboratories were first introduced into Universities and then into Technical Schools. Men who have received their instruction in Universities in which methods suitable for advanced students alone were used come out into the world as teachers without any suggestion as to the methods which should be employed for beginners. There is small reason

to wonder then that much of the teaching resolves itself into an abridged edition of the University course.

If such a man goes into a secondary school he soon finds that these methods are impracticable in the case of boys. Moreover, he is then in close touch with other teachers who have had some experience, and from them he learns to avoid common mistakes, and acquires some of the wisdom which has yet to be tabulated and organized into a science of special method. But in a Technical School a teacher is more frequently an isolated unit, left to plough a lonely furrow, hemmed in on all sides by a curious kind of professional etiquette which forbids method being discussed, and living in an atmosphere which regards method as suitable only for teachers of small children. It is some time, therefore, before he learns that most beginners are precisely in the position of little ones, with the same difficulties, and requiring very much the same methods to overcome them. Then, again, though he should come to a conclusion as to what constitutes the best method he meets with obstacles in the way of its introduction which reach their greatest strength in Evening Technical Schools. To begin with, the students only have a limited time. Next, the movement in favour of laboratory work has developed more rapidly than laboratory accommodation. His use of the laboratory is often limited to a sharply defined period on one evening a week. Thus cases are known in which the Mechanical Laboratories are occupied on every evening in the week, and the classes have to pass in and out with mechanical regularity. But two things are clear. For effective teaching in the early stages some of the work must be done by the students themselves, and this must precede any discussion or extension of the results. The plan by which at a particular time some students are doing work which has been discussed and exhausted some weeks ago, while others are drawing conclusions from experiments which depend upon that which has not been discussed at all, is pernicious in the

extreme. When a class has acquired a fairly full outline of the subject, and has become familiar with the construction of apparatus and method of carrying out experiments, the order of experiment is of less importance. But even here a promiscuous order is not to be entered upon lightly. In the first year at a new subject the order is fundamental and cannot be departed from without seriously impeding the student's progress.

If a close connection between theoretical and practical work is to be secured, it is clear that the students must do similar work at the same time in the laboratory. In Chemistry and Elementary Physics this has always been possible in recent years, because the apparatus is simple, inexpensive, and readily multiplied But in Mechanics the apparatus is as yet on the University plan In many cases only one instrument for each purpose can be obtained, and the teaching has necessarily approximated in method to that at the universities. The adoption, however, of the methods of teaching outlined in Chapter VI enables the students to make uniform progress in the laboratory work with a minimum of multiplication.

For this purpose the work is arranged in sections, each dealing with a group of cognate ideas and *including several experiments*. Thus in dealing with the properties of materials the teacher first discusses with the class the different ways in which forces can be applied to structural materials. They consider the best way in which to produce and measure extension, compression, bending, and torsion, and decide that the data they want are the amounts of deformation produced in a given case by given forces under certain conditions, whether these are uniform over a particular, or any, range of experiment, and so on. After that it is not a matter of very great importance which experiment is attempted first. The eight or ten experiments comprised in the section are then distributed round the class. As each pair of students obtain the required data from one apparatus they change over with another pair, until the

whole of the experimental results have been accumulated. The students then discuss results, and with the help of the teacher consider the whole question of elasticity so far as it is necessary at this stage. They then proceed to apply their knowledge to examples, and afterwards are ready to start together at the next section.

It will be obvious that the usual division into theoretical and practical lessons is departed from. A class may spend two or three nights in the laboratory, a theoretical lesson coming before and after the experimental results have been obtained. Occasionally a section may occupy only one evening.

In some cases an experiment is carried out by the teacher within the section—that is, a demonstration in the laboratory which supplements or extends the student's own work. By the judicious employment of this method the rapidity of progress is quite equal to the old method, and infinitely superior in point of effectiveness. No student ought to be expected to waste time over an experiment from which he can learn as much when it is performed more accurately and expeditiously by the teacher. Moreover, the latter should always be prepared to set up special experiments to extend and broaden the student's knowledge of principles, properties, and phenomena. Many a man to-day owes the beginning of his scientific enthusiasm to the trouble which an older generation of teachers took over experiments which were outside the range of the syllabus.

This plan of sectionalizing the work can be applied to any branch of experimental science, but it is peculiarly useful where the cost of laboratory equipment is excessive. The method of putting experimental work by the students first has the merit of avoiding a somewhat prevalent error which so frequently appears in syllabuses that its meaning cannot be widely appreciated—that is, the suggestion that the student goes into the laboratory to *verify* physical laws. A physical law is beyond verification by an elementary student, and the suggestion

that he should attempt it is an insult to the distinguished men who have preceded him. Through experiment the class are led to see more or less vaguely the existence of a law; their results added to others which are obtained from teacher or text-book help them to state it. Every successful application is then further verification.

This leads to another point. The name of the law follows the mental appreciation of the relation between facts or phenomena which the law expresses. Without these facts the name is useless. It is a mere label, and until the student has acquired the ideas, has reached the generalization, and can express in words what he has learned, the label is a nuisance—a piece of useless lumber of no mental value whatever. It is wrong, therefore, to preface a lesson on the elasticity of gases by writing "Boyle's Law" on the blackboard, or to introduce a lesson on elasticity of structural materials by referring to "Hooke's Law."

The fundamental order in the early stages is, firstly, the ideas; secondly, the generalization in words; thirdly, the short title or label by which the parcel of knowledge will subsequently be known.

A word is perhaps desirable in reference to a curious plan which has achieved a somewhat wider popularity than it deserves—that is to throw the student on to his own resources in the laboratory. He is sent into the room, given some apparatus, told to do something, and to observe what happens.

A very elementary acquaintance with Psychology tells us that observation is not an external effect only, but a reaction between what is in the mind and what is outside of it. A novel presentation arouses a kind of crude recognition which is of no particular educational value, and intellectual recognition presupposes a certain amount of mental preparation. People observe what they have learnt to observe, and observation is only an outward and visible sign of an inward and invisible mental picture.

The first observation of the varying colours upon a copper plate when it is heated was not made by an average man—not, at any rate, in the sense that it constituted a distinct addition to exact knowledge; and it is hardly fair to expect a young student to do in a few minutes what thousands of men failed to do in a thousand years. If he is to pursue the path to knowledge which has been taken by the race, he must be allowed a reasonable time, and if he is to make any useful progress he must be helped over some of the difficulties which formerly proved to be insuperable barriers for a longer period than he is likely to live. The teacher and the school are there to help him over the initial steps, and to put him in possession of what has been done before his time. It is the teacher's special function, by appropriate suggestion, to direct his attention to the things which it is important that he should see. Observation cannot, as Adams says, be trained by providing the pupil with materials to gape at. In that case the pupil merely gapes.

Similarly, the notion of setting the student to perform an experiment without aid or suggestion, is open to criticism. If he has a natural aptitude for experiment, trained by various pursuits followed before entering the school, it may be good, and with an advanced student it is admirable. But to attempt it promiscuously with beginners is not only to court failure, but to act unfairly in setting them to do what the intellectual giants alone of a former age were able slowly and laboriously to accomplish. It is the supreme test of the teacher's judgment that he knows what to tell the students, and what to leave them to find out.

Applied Mechanics

In considering what shall be the scope of the first-year course some debatable questions arise. The existence for many years of two syllabuses—one in theoretical and the other in applied mechanics—has contributed to an arbitrary, and somewhat

undesirable separation between the science of mechanics and its application. So long as some students attended classes in both subjects no great harm was done, because they represented the most serious and ambitious element, who also would, in most cases, stay some years in the school. But now that theoretical mechanics has practically disappeared from the time-table it is necessary to reconsider the scope and character of the syllabus in applied mechanics. In this, as in other subjects, tradition must be swept ruthlessly to one side, and regard must be had only to the circumstances which have to be met.

The problem, then, is to provide a year's work in Mechanics which will occupy one evening a week for about thirty weeks. It must be suited to the student's stage of mathematical progress, within the range of his industrial experience, and provide a broad and solid foundation for subsequent studies.

First let us glance at the scientific "content" of Mechanics :—

MECHANICS

- Statics
  - Two laws of equilibrium
    - Σ(Components) = 0
    - Σ(Moments) = 0
- Kinetics (including Hydraulic
  - Three laws of motion with corollary to the thir
    - Force changes Motion
    - Force ∝ change of Momentum
    - Action = Reactio and Principle of Work

Next let us look at the applications. They are :—

(1) Properties of materials which underlie all design.
(2) The distribution of force in structures.
(3) Appliances for transmitting motion.
(4) " " " force.
(5) " " " work.

The two schemes indicate broadly the difference in conception of theoretical and applied mechanics. The one emphasizes the principles involved, and the other the application of these principles in industrial life.

In accordance with the principles of teaching which have been enunciated the course should be so designed that the student arrives at the mechanical truths through the practical study of materials and contrivances in which his interests are for the time being centred The work will be arranged in sections in order—

(a) To bring out more clearly the logical structure of the subject, and

(b) To enable the students to be kept together.

Each section will contain -

(1) An initial discussion on the aim of the section and method of experiment

(2) The performance of experiments by the students themselves, and in some cases by the teacher

(3) A final discussion of the results followed by the working of exercises, chosen to emphasize the truth and extend its applications.

In the last stage the teacher will lay stress on the difference between a law and a definition whenever there is liable to be any confusion between the two.

It will be assumed that the students have passed through a preliminary technical course or its equivalent, and that they have some notions derived from experience and teaching of matter and force, motion and time In addition to this, they ought to have a growing acquaintance with the idea of moments and the composition and resolution of forces. On this understanding we proceed to --

SECTION I.—*Stress and strain*. Questions are asked as to the effect of force upon *e g*, a rod of some material so fixed that it cannot be translated bodily to another place. The various ways in which a force can be applied, and the probable effect which will be observed are then elicited from the class. The importance of obtaining exact knowledge is emphasized,

and the students are asked to say how they would propose to fix the piece of material, how they would propose to apply the force, and approximately what weights they consider they will require.

This, while it leads to very little external result, serves to train the students' minds upon the nature and conditions of the experiment. All four cases of bending, stretching, compression, and torsion, should be considered, and possible combinations should be noted. Some teachers would exclude torsion at this stage, but it seems desirable to give the students a broad view of the whole field, and torsion only becomes difficult when the internal stresses are considered.

With two sets of apparatus for some experiments and three for others, twenty to twenty-four students would be accommodated at once with ease. The apparatus for springs and beams is easily duplicated. The former may be 4 ins. long and capable of stretching 2 ins. with a load of 12 to 15 lbs., and sufficiently accurate results can be obtained by measuring with an ordinary scale the distance between the first and last coil. Similarly the laths may be of wood or metal from 3 ft. to 5 ft. long, clamped to the underside of a table top, and the deflection measured from the table downwards, or from the floor upwards.

It is very desirable that at this stage the students should load a wire to destruction, and plot the load-deformation curve, in order to obtain clear notions of the elastic and non-elastic behaviour of materials. Soft copper and steel pianoforte wires are suitable for comparison. Moreover, in the case of the elasticity experiments the students should use the curves they have drawn to determine an unknown weight by suspending it from the spring or lath and noting the deflection. At the conclusion of the experimental work the teacher will discuss the results, define Young's Modulus, and show how it is obtained from experiments on the extension of a wire. This should be followed

by examples to be worked at home and, so far as there is time, in class.

SECTION II.—*Parallel forces, moments, and couples.* A preliminary experiment should be performed to show that the upward forces on a body balance the downward forces, if, and only if, a few questions have shown that the students are unaware of this. If small sportsman's spring balances are used it can be seen at once that the sum of the upward forces only equals the sum of the downward forces, when all are parallel.

The students own experiments are performed more quickly if one end of the rod or lever is supported by a spring balance, and the other end has a sliding weight The distance on the "balance" side then remains constant The idea of a "moment" is best obtained by using several discs mounted on the same axis. The forces are applied to the periphery of these discs by cords and sportsman balances The results are summarized in the principle of moments, and this is applied to simple practical examples on beams and girders. The steel-yard should receive very brief treatment at this stage as an application.

Very often bending moment and shearing-force diagrams are drawn in the first year, but it is rather difficult to see what purpose they serve. If bending moment is to be understood the moment of resistance must also be introduced. There is no very great difficulty about this providing the idea is developed carefully.

Once the idea of moment of resistance is clear an explanation of the cross-section of cast-iron and steel joists, and the real meaning of stiffness, becomes apparent The teaching has then served a useful purpose, because it has given an intelligible reason for a particular construction. But this is certainly as far as, in ordinary circumstances, the subject should be carried, and shearing force diagrams may in any case advantageously be deferred until the second year.

SECTION III.—*The triangle of forces and its application.* The chief error to be avoided in dealing with non-parallel forces acting on a body in equilibrium is to beg the question that they meet in a point. If this part of the work has not been dealt with in the preliminary course, the following is a good method of attack :—

An irregularly-shaped piece of card with a number of holes pierced near the edge rests on three bicycle balls, or three good marbles, on a sheet of paper on a table. One, two, and then three forces are applied horizontally to the card by hooking spring balances or graduated rubber balances to the holes in the edge of the card, and the direction of the strings in each case marked on the paper. The following observations are made :—

(a) With one force the card tends to move in the direction of the force.

(b) Under two forces the card is in equilibrium when the forces are equal and opposite.

(c) When two of the forces are opposite the third is zero, and it gradually increases as the angle between the two decreases, until, when they are parallel, it is equal to their sum.

At this point the parallelogram and triangle of forces can be explained and applied to simple cases. It is desirable to extend the last two sections at this stage by dealing with the resolute of a force. This enables the second law of equilibrium to be stated, and the whole work of the second and third sections can be summarized in the two laws—

$$\Sigma(\text{Components}) = 0, \ \Sigma(\text{moments}) = 0.$$

Applications will be made to cranes, guy-ropes, and simple roofs, and additional experiments can be introduced if necessary.

It will be observed that some of the experiments are complicated by friction, and the existence of this should be recognized.

But it is not desirable to trouble about the exact numerical value of this until the transmission of work is being considered.

It is conceivable that there may be considerable difference of opinion as to the scope and order of the remainder of the session's work. That which has been outlined up to the present occupies about ten weeks—more or less according to the capacity of the class, the "grip" of the teacher upon his subject, and his power of organizing laboratory instruction.

Normally the scheme would proceed as follows —

SECTION IV.—*The transmission and conversion of motion.* Belts and pulleys, gearing, crank and connecting rod, cams, simple straight-line linkages. The object here is two-fold—to familiarize the student with the devices involved in machines, and to sharpen and extend his experience of motion.

SECTION V.—*Velocity and acceleration.* This involves the measurement of time, and the experiments should include observations on the relation of the time of swing of a pendulum to the length. At the discretion of the teacher the oscillation of a weight attached to a helical spring, or a mass on the end of a thin lath may be included.

It is difficult to arrange accurate experiments on time or velocity and recourse must be had to the experiences of everyday life. A good deal of practice should be given in plotting displacement diagrams.

The simplest experiments in acceleration are furnished by a body rolling down an inclined plane The sphere rolling in a groove is unsatisfactory, but a heavy disc on a long axle which runs on inclined rails is excellent. A wire stretched across the laboratory with a carriage supported by a pulley gives fair results, and a good Fletcher's trolley is excellent for the purpose. Whether the question is to be treated fully at this stage must depend upon the capacity of the class. What is required is a basis for the dynamical definition of force, and this is necessary

if kinetic energy is to be understood. It should be obvious that force tends to change a body's state of rest or motion even though the full significance of the law is not immediately grasped by the student. But it is not always made clear to him that the absolute unit of force is merely a definition of the same kind that determines the length of the metre. If gravitation is not understood the teacher may deal with it on the lines laid down on page 103. After that numerous examples should be worked on momentum, using both absolute and gravitation units, until the student becomes fairly familiar with the relations.

There may be some disappointment with the result of the teaching at this stage because the conceptions are not easy, but there will be more if they are shirked. The main point is to secure a ready working acquaintance with the subject rather than the ability to recite hair-splitting definitions.

SECTION VI.—*Machines*. A machine may be regarded from three points of view.—

(*a*) A contrivance for transmitting Motion.
(*b*) " " " Force.
(*c*) " " " Work

The character in the first aspect is indicated by the velocity ratio, in the second by the mechanical advantage or force-ratio; and in the third by the efficiency. It is desirable to consider (*a*) and (*b*) first, and to reserve (*c*) for the next Section.

Its velocity ratio should be found experimentally, and checked by calculation. A number of displacements of the points of application of the effort and load may be plotted one against the other. The slope of the line then gives the desired ratio. Similarly the load and effort should be plotted, and the equation to this curve determined. This should be compared with the equation derived on the assumption that there is no friction. The difference gives the friction equation in terms of the load.

The actual determination of the friction constant with various surfaces would be appropriate at this stage

SECTION VII.—*Machines (continued)*. It is proposed now to deal with the efficiency of a machine. If work and power have already been discussed this is easy, but for some reasons it is desirable to defer that question until the next Section.

The method of dealing with efficiency here is as follows:—

The *real* load for any effort has been found by experiment in Section VI, and the *ideal* load for any effort can be calculated from the equation of force-ratio on the assumption that friction is non-existent. The ratio of the *real* to the *ideal* load is the efficiency of the machine

The efficiency curve is then plotted and checked by applying some effort which has not been used before and reading off the load. The advantage of this plan is that the student uses his previous experimental results to develop new knowledge.

SECTION VIII.—*Work and Power* This section will review the whole of the experiments on machines, and develop the principle of work and ideas on the rate at which work is performed

Note—The machines studied should include a train of gearing such as a builder's winch, rope pulley tackles, a screw, a worm pulley tackle, a simple and compound wheel and axle

Much time may be saved if a light spring balance for measuring the effort is used instead of the customary scale pan and small weights

Apart from Engineers there are two other groups of students who attend classes in Mechanics—those engaged in the Building and Textile Trades—and it will be desirable to say something about their requirements. Usually the Builders will take the subject in their second year at the Technical School, and their mathematical equipment will be more modest. On that account it is necessary to rely to a greater extent upon the graphical

methods of calculation. They want to know something of work in connection with the lifting of weights and the mechanical advantage of various forms of lifting tackle. In addition they need similar instruction to first-year Engineers on torsion, compression, extension, and bending, and a rather fuller treatment of girders and roofs. Torsion is a matter of little or no consequence, but beams and roofs should be dealt with as fully as in a course for second-year Engineers.

The requirements of Textile students fall into two divisions. Firstly, they need information on the transmission and distribution of power in a factory, and, secondly, they need a somewhat exhaustive treatment of devices for transmitting of motion.

The examples in mechanism should be chosen largely from the spinning and weaving machinery. It is doubtful whether a full session's work is really necessary, and it has been proposed that half a session shall be spent on mechanics and half a session on mechanical drawing. The mechanism would certainly involve a good deal of plotting loci, and it seems feasible to combine this with the drawing of the actual mechanisms involved.

Electricity and Electrical Engineering

Hitherto there have probably been more difficulties associated with the teaching of this subject and Chemistry than with any others falling within Technical School curricula. These have arisen partly from the fact that students of varying age, different experiences, and widely divergent aims, have presented themselves for instruction; and partly because the numbers have not, in most cases, permitted alternative schemes, differing in scope and character, to be formed. The influence of the course system is, however, making itself felt, and the students are becoming more uniform, at least in age and preliminary training.

The scope of the teaching has usually been determined by

the syllabus of the Board of Education in Magnetism and Electricity, and by the syllabuses of the City and Guilds of London Institute in Electrical Engineering, Telegraphy, Telephony, etc. In most cases the student has been required to attend a class in the first stage of the Board of Education syllabus, prior to or concurrently with, the lowest stage of the City and Guilds subject. There is a very strong feeling, however, that this involves a good deal of repetition and much waste of time. The chief recommendation is that the City and Guilds' syllabuses cannot be covered adequately in one year by students who have no previous knowledge of the subject. The teacher has to choose, therefore, between a somewhat sketchy treatment of the technological subject and an academic and prolix scheme involving the old syllabus of Electricity and Magnetism.

The tendency is to adopt a scheme which, while it omits nothing that is of fundamental importance in explaining the applications of science, does not shy at the discussion of practical instruments and methods that are within the range of interest and comprehension of elementary students.

For many reasons it is desirable that a student should not enter upon this subject until the second year at a Technical School. Chief amongst these is the fact that Electricity is a dynamical science, and the later it is introduced into the course the more rapid is the progress which can be made in it. In no other subject is it so necessary to have an effective preparation in mathematics and mechanics.

In mapping out the course the teacher will naturally have regard to the desirability of grouping the experiments wherever the failure to do so would lead to the divorce of theoretical and practical instruction. Even when the apparatus is sufficient to enable all students to undertake the same experimental exercise this grouping may be advisable, because it tends to bring into relief the logical structure of the subject. A set

of experiments included between two theoretical lessons—an introductory review and a summary and extension—always produces a larger and more coherent body of knowledge than is possible when the monotonous lecture-laboratory-lecture-laboratory-order is followed. Moreover, it is then always possible to ensure that the theoretical discussion is so related to the practical work as to produce the maximum effect.

To proceed to a detailed scheme, the method and order of treatment of Magnetism offers little scope for originality. The first essential is to secure a clear mental picture of the magnetic field, of the effect of magnetic material in altering the distribution of force in the field, and of magnetic induction. The simple facts of terrestrial magnetism are necessary in order to understand galvanometers, etc., but the treatment may be very brief, and refinements of measurement of the earth's magnetic constants are not necessary to the student's subsequent progress. Thus the comparison of moments with a simple magnetometer may be desirable, but the effect of a magnet on a needle when the former is in the A and B positions of Gauss is not required. It should be clearly understood that this suggestion is not based upon a *penchant* for premature specialization and short cuts. The Science of Electricity and Magnetism is no more Electrical Engineering than is the Science of Mathematics. The complex applied subject is not a simple addition of separate sciences, but a fusion of certain elements in each.

A most profitable exercise at this stage is the drawing of fields of force to represent various arrangements of magnetic bodies. At first these should be done experimentally; later they should be drawn first and checked by subsequent experiments. In this way the student obtains a clear idea of the properties of the space surrounding a magnet, and this conception is essential to intelligent progress.

The next stage is usually the production and properties of an electric current. This is not difficult if the students have

done some chemistry; but if they have not, the teaching necessarily becomes didactic—and disappointing. It is perhaps desirable to run lightly over the chief effects of a current at this point, and then to select the magnetic effect for particular study.

The effect of a current on a magnetic needle leads to a consideration of galvanometers. The preliminary experiments will show the effect of—

(a) Increasing the thickness of the wire;
(b) Increasing the number of turns,
(c) Distance of wire from needle;
(d) Advantage of a circular coil for measurement.

A good deal of time is frequently taken up in the classroom by long descriptions of the different types of instruments. It is far better for the students to examine the different forms in the laboratory, to sketch them, and to accompany their sketches with simple descriptions.

A very simple form of galvanometer may be used to give some idea of resistance and fall of potential, and these phenomena lead to definitions of E.M.F., C., and R. In order to fix Ohm's Law some measurements of the three quantities will be made in the laboratory, but the exercises should be grouped, and over-elaboration should be avoided. Wide knowledge and a high degree of skill in these determinations must be obtained under more favourable conditions in the testing-room. In the school at this stage they are incidental to the clear apprehension of Ohm's Law. Almost, if not quite, of equal importance is the working of a number of numerical exercises on the same topic, but illustrating a wider range of conditions.

The three topics which now call for treatment in some detail are:—

Electromagnetics,
The heating effect of a current,
The chemical effect of a current,

and there may be some difference of opinion as to the order. Up to this point the scheme has not differed much from an ordinary course in Electricity and Magnetism. The properties of an electromagnet and of a solenoid, and the heating effect of a current provide opportunities for explaining the construction of commercial measuring instruments, of glow-lamps, and of one or two simple forms of arc lamps. These should be studied at first hand in the laboratory, and sketches and descriptions entered into the note-book. A parallel treatment may be accorded to the chemical effect. Primary and Secondary batteries may be examined in the laboratory, and a few examples of electro-deposition may be introduced.

In some cases it may be desirable to defer the consideration of the chemical effect until later, so as to follow, with as little interval as possible, the magnetic effect of a current, induction, and its application to dynamos and motors. The character of this portion of the work will necessarily vary with the equipment. In many schools the number of students will hardly justify an expensive equipment which will enable all the students to be kept together. If the teacher has to choose between a demonstration and a variety of experiments which involve the divorce of theoretical and practical instruction, there is no question as to which is the soundest method. But this statement must not be taken as indicating a preference for a limited equipment. It is merely a piece of advice upon a choice between two evils, which is not to be commended in any but temporary arrangements. Electrical Engineering demands adequate provision of apparatus, and it cannot be taught satisfactorily where this is insufficient. We are dealing here with an eminently experimental subject, which must be taught by laboratory methods. Success depends upon—(*a*) An adequate preliminary training; (*b*) A proper relation between theoretical and practical instruction.

There is one other point which has so far escaped discussion —that is the inclusion of electrostatics. Formerly the topics

included under this head, received an amount of attention quite out of proportion to their importance—not to Electrical Science, but to Electrical Engineering. Even now it is impossible to ignore them entirely. But in the first year only just so much should be included as will explain the action of the Electrostatic Voltmeter and the Condenser. The former will be described by analogy with the gold leaf electroscope; the latter by analogy with the Leyden jar. But even these may well be left to the second year.

Chemistry and Science for Particular Trades

Chemistry

In view of the voluminous writings on the teaching of Chemistry which have appeared during the last twenty years, an abject apology would seem to be necessary for this chapter. The aim of most of those who have hastened into print on this topic, however, has been the teaching of Chemistry to schoolboys. Upon this and, indeed, also upon the teaching of Chemistry as a science, we have nothing to say. With a class of schoolboys having a reasonable amount of time, and no immediate professional or industrial needs, much can be done. But in the Evening Technical School the teacher frequently has to deal with a class in which the age, previous education, and industrial requirements vary enormously.

The usual practice is to provide a scientific course of Chemistry which, if pursued for a sufficiently long time, will surely throw light upon those industrial processes in which the student is interested. The effect of this is well shown in the difference between the first and third-year class. The former may contain teachers, students working for a University degree, dental students, pharmaceutical chemists, students engaged in works laboratories, students engaged in the process of dyeing, or

bleaching, or tanning, or soap-making, or alkali and sulphuric acid manufacture, or metallurgy. The latter contain a few students working for degrees, and a few engaged in works laboratories. Nearly all the students of lower calibre have left the class.

The essentially physical basis of Chemistry requires that a good deal of the first-year work should consist of Physics. There is a natural tendency to slur over this, and the study of the higher stages suffers in consequence. Again, the extensive range of Stage II. as compared with Stage I. has generally led to the latter being divided into two sections, covering two years. It is, however, rather difficult to make a happy division of this syllabus, and it is better to re-arrange the scheme entirely. The introduction of Physics, with special reference to Chemistry, on one night a week in the first year enables more ground than is represented by the old Stage I. being covered in the first year, and lays a good foundation for Stages II. and III. in subsequent years.

A natural result of the controversy on the teaching of Chemistry has been to stereotype method. While in some respects this is all to the good, it is most desirable that the teacher should seek to ascertain upon what kind of work his students are engaged in the day-time, and with what substances they come into contact. This knowledge will frequently enable him to select a substance or a process the nature of which will at once chain the attention of the class. The establishment of a principle will then be much easier than if it had been attempted through an unfamiliar substance or process.

Not only should the students' everyday experience form the starting-point whenever that is possible, but it should influence largely the kind of practical work undertaken in the laboratory, and the nature of the processes discussed in class. This utilization of the range of industrial knowledge and interest is analagous to the method of utilizing the common knowledge

and interest of schoolboys, and is equally valid. It marks the only real difference between the teaching of Chemistry in the Secondary and Technical School.

It will be well to look for a moment at what this principle involves. The student engaged in Alkali and Sulphuric Acid works will require emphasis to be laid on sodium compounds, and on acidimetry and alkalimetry. The student engaged in a metallurgical works requires a rather fuller treatment than usual of oxidation and reduction of sulphur compounds, and the effect of heating them in a current of air, and hence of the recovery of metals from their ores The very considerable variety of interests that are represented in some classes will render specialized teaching of this character impracticable, but there are numerous cases in which the students can be divided into two or three groups, and then an occasional theoretical discussion following special work in the laboratory will be both possible and beneficial

In many places arrangements are made for the students to visit gas and chemical works during the session It is very desirable that such visits should be preceded by an account of the materials and processes involved Only in this way, as a rule, can the students benefit from an inspection of apparatus which is so different from that which they use in the laboratory, or from that with which they are familiar in their own industry. As in all other cases, they have to be taught what to "observe"; and without preliminary knowledge it requires a fine effort of the imagination to realize what goes on inside a sulphuric acid chamber! This example may be heartily commended to the "observational" and "throw-a-student-upon-his-own-resources" schools of educational reformers.

Perhaps a few suggestions might be offered upon the Physics to accompany the instruction in Chemistry. This will ordinarily include determinations of specific gravity, thermometry, melting and boiling points, vapour pressure, the thermal properties of

gases and specific and latent heats, followed by about ten or twelve lessons in Magnetism and Electricity. The first eighteen or twenty lessons would be devolved to physical experiments on the substances examined in the Chemistry class. The last portion would seek to lay a foundation for the electrolytic theory of solution. It is hardly possible to include such matters as pyrometers and the kinetic theory of gases at this stage, and where some special knowledge of this kind is required it is better to arrange a short course in the summer months.

Before leaving this subject it will be desirable to offer some remarks upon the scope of the laboratory work.

In the first year there is usually a fairly close connection between the theoretical and practical work. Beyond this, however, the latter tends to degenerate into mere test-tubing, and to have little or no relation to the work done in the lecture-room. There is now a wide scope for the development of a much closer connection between the student's own work and the teacher's extension of it in the second year of the course. A sudden plunge into systematic analytical processes is undesirable, because as a general rule his mind-content is neither large enough nor sufficiently systematized to enable him to appreciate the methods. He learns by rote, and performs experiments mechanically.

The most satisfactory plan is for a series of preparations and reactions to be studied in the laboratory, and for the theoretical teaching to be based upon these. Preparations and purifications involve analytical processes, and in performing them the student gradually acquires that mental background without which systematic analysis is unintelligible.

Science for Particular Trades

There are a number of trades for which some knowledge of Chemistry and Physics is required, and in which it is extremely

difficult to persuade the students to attend the ordinary science classes. Thus, in addition to builders there are metal-plate workers and men attending an engineering workshop course who ought to have some instruction in the chemistry and physics of materials. In many cases the standard of admission to these classes is low, and the students have very little mathematical ability, or of that command of language which is essential for scientific studies It will therefore be desirable to make some suggestions as to the method of treatment.

The scheme for builders is fully set out in one of the books of the series to which this volume is an introduction, so that one or two notes only are necessary here. The first point is to see that the science work keeps in the closest touch with the trade class. The order of treatment is determined largely by the order of the teaching in Building Construction Each section should be introduced if possible by a problem in Building (*Cf.* the example in Chapter V), and the scientific principle acquired must again be applied to the elucidation of further practical problems. As this part of the instruction will generally be in the hands of a Science teacher, he should endeavour to acquire some knowledge of the trade materials and processes but more particularly he should make an effort to establish friendly relations with the teacher of the trade subject.

In the early part of the course just so much geology should be introduced as will explain the origin and structure of the raw materials, and it is of fundamental importance that these shall be examined and compared in the laboratory. The teacher must avoid at all costs the encyclopædic type of teaching into which it is so easy to fall. What the books say and the teacher repeats is of small consequence compared with what the students actually find out from their own observations. The nature of the material used in the school itself should be noted, and the attention of the class should be directed to the materials employed in their own homes and in various public buildings in the town.

This is the best way of acquiring information about appearance in bulk, and durability

The school again is an effective starting-point for a discussion of heating, ventilation, and lighting. The teacher's own judgment here will prevent him from falling into the error of superior criticism A great many school buildings have a pleasing exterior, while the interior contains many illustrations of technical ineptitude, but an elementary class is not a body to whom complaints can usefully be made.

Instruction for metal workers should comprise a qualitative experimental treatment of the properties of the materials they use. Thus they should learn that some bodies are quite elastic within limits, and others plastic even to small forces. A clear picture ought to be developed as to what occurs when a bar of metal is stretched, compressed, bent, or twisted to a small extent. The tendency of metals to "flow" should be illustrated by the processes of "spinning" and beating out sheets, and by wire drawing. A very elementary course in heat would involve the explanation of melting and boiling, approached through the effect of heat upon alloys The necessity for some flux to protect the hot surface from the air would lead to notions of oxidation and reduction, and to a fairly clear picture of combustion. It may be observed that this order is the reverse of that usually followed in Elementary Chemistry. The secret of success here is not to teach the nature of the processes through chemistry, but to attempt to teach chemistry through the trade processes. The teacher should realize that substances through which chemistry is usually taught are an accidental selection. If the only people who required chemistry originally had been metal workers the books would have been quite different. Most elementary books on chemistry are designed to appeal to the minds of schoolboys. In this case the teacher has to appeal to the minds of metal workers, and he must alter the method accordingly.

CHAPTER XII

THE TEACHING OF CONSTRUCTION

IT will now be desirable to discuss the more strictly Technical Subjects—Machine Construction, Building Construction, etc. As the names imply, these involve the study of construction, though they have been, and still are, interpreted as excuses for mere pencil play. In industrial life drawings are used to convey ideas from the architect or designer to the workman, and the proper place to acquire this ability is in the drawing-office, where the long hours permit of that skill which is necessary being obtained. The function of drawing in the school is rather different. There it enables the student to acquire exact notions of proportion and general arrangement. Incidentally he learns how to make and read drawings, and thus becomes familiar with the language of construction, as well as with construction itself.

A close examination of many examples will show that three considerations are involved :—

(1) Materials and processes.
(2) Strength.
(3) Common sense.

In the earlier stages the more important are (1) and (3). At a later stage the student's shop experience enables him to deal with these factors subconsciously, and he concentrates his attention on strength. In the first year, therefore, the class should confine their attention to the simpler constructions.

They may calculate weight, volume, and quantity of material required, but they should not go deeply into questions of strength until they have obtained in the laboratory that quantitative knowledge of the properties of materials which is necessary for design. If this rule is broken the tendency is to produce students who can design things that may not work, or are incapable of being made, or whose construction would involve

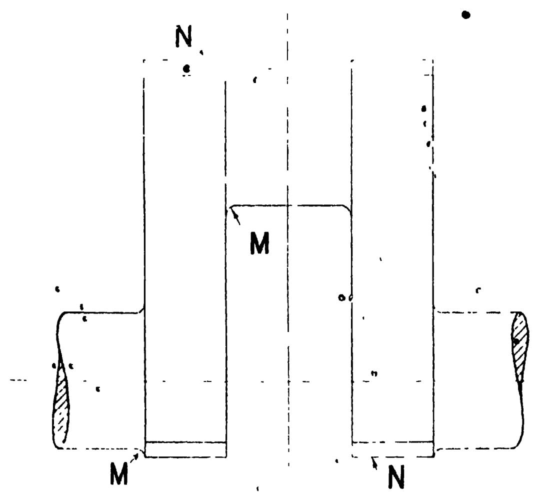

FIG. 1.

too great a cost. A sort of practical instinct has to be developed through which scientific calculation can safely operate.

It will be desirable to deal first with *Machine Construction*, and it will be assumed that in the Preliminary Technical Course the students have learnt to draw the common regular figures, and to project a simple solid, such as a brick. The initial step should be to secure a proper method of setting out the work. For this purpose a model of a simple crank (Fig. 1) or similar

detail may be chosen, of which three views are required. The students should measure up this and make sketches of it in a squared-paper note-book. If there are not sufficient cranks to go round, other simple objects may be used.

The students may be asked: "What scale is to be used?" They are then told to draw the object in the following stages:—

(1) The horizontal centre lines
(2) The vertical centre lines
(3) Distances of outline each side of vertical centre lines.
(4) The vertical lines of the object with set squares, and the circles.
(5) Distances of outline each side of horizontal centre lines.
(6) The horizontal lines of the object with T-square.

At this point the following questions may be asked —

(*a*) What should be the radius of M? What tool is used to make this? If the radius is too small what is the effect?
(*b*) What should be the outline of ends N? How would these be machined?
(*c*) What is the smallest number of views from which all the dimensions could be obtained?

In common with other subjects which have been discussed, the work for the session should be arranged in sections, each dealing with a closely associated group of constructions This can be interpreted in two ways. According to the first plan the constructions to be grouped can be similar in the sense that they are intended to perform the same functions in different machines. According to the second plan the constructions can be grouped so that when taken together they form a more or less complete machine. The first is that of the standard book on Machine Design, and, indeed, it is doubtful whether a book, to be of wide value, could be arranged in any other way. Thus there is a section on bolts and nuts, another on

rivets and riveted joints, a third on keys and key-ways, a fourth on cranks and crank-shafts, a fifth on wheels and pulleys, a sixth on connecting rods, a seventh on pistons, an eighth on bearings, a ninth on valves, and so on. But if the students follow this arrangement closely they learn to draw detached details, and do not realize the reason why the various differences of form and construction have been adopted. Moreover, it tends to become dull. What can be less inspiring than to spend a week or two drawing rivets, and another week or two on keys and key-ways?

According to the other plan a series of simple machines is chosen which are of interest to the class in view of the local industry. If the latter is varied the class can be taught in sections. The fact that the type of machine made locally is complicated does not necessitate the complicated form being undertaken in the first year. The main point is that the student shall understand clearly the purpose which the machine has to achieve, and that he shall be able to concentrate his attention on the means taken to attain the end.

In order to illustrate this method an example which might follow the crank shaft will be given in detail. A B in Fig. 2 represents a heavy piece of timber, and C the end of a shaft for which a bearing has to be provided. Set the class to sketch the outline of such a bearing. This is criticized, and a model similar to that shown in the figure is exhibited. The following questions are then asked :—

> Of what material would this be made? Why?
> Why does the sectional area of the webs increase as the base is approached?
> Why are the corners rounded out?

After discussion the class is set to draw the bolts and nuts separately, and then to draw a section on X Y.

Incidentally the students may learn something about

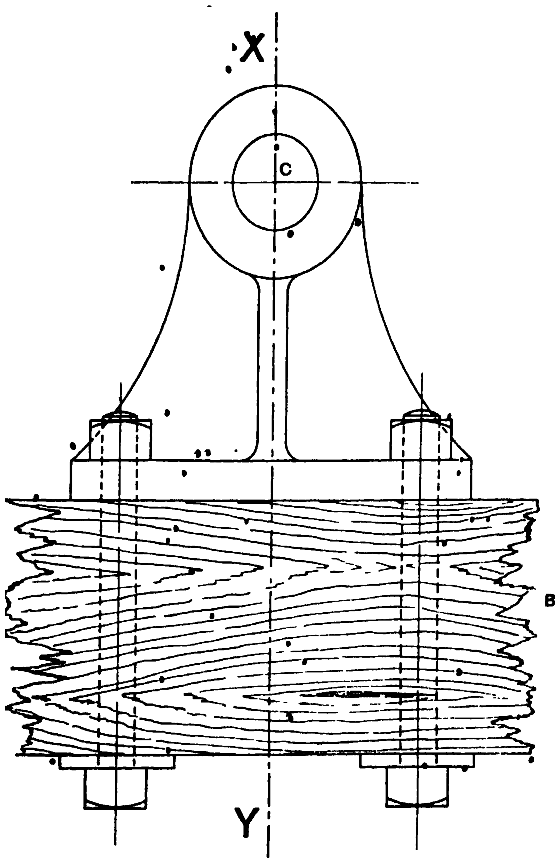

FIG. 2.

moulding and casting, the proportions of bolts and nuts, and a cotter. As an exercise an actual example or model may be given to be sketched and drawn, and then treated in a similar way.

The example may be extended by drawing a straight or bent lever, which is keyed on the end of the shaft (Fig. 3) Questions are asked as follows:—

(*a*) Of what material is the lever made? Why?
(*b*) If of wrought iron what would be, roughly, the shape of the section?
(*c*) If of cast iron what would be, roughly, the shape of the section?
(*d*) Where would the key-way be cut in the boss, and why? (*See* Fig 4.)

This exercise may be followed by sketches of similar contrivances from the model or actual object, and by calculations as to weight and cost. It will be observed that the workshop aspect is predominant, and that bolts, nuts, cotters, and keys are dealt with incidentally. Subsequently other simple machines such as a drilling machine, lathe, line of shafting, small steam engine, gas engine, or pump may be attempted, choosing that which is closest to the everyday work of the class. Models should be used as freely as possible, in order to—

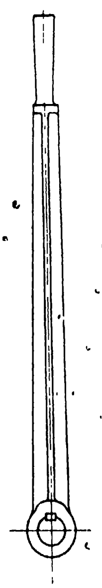

FIG 3

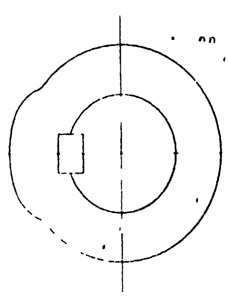

FIG 4

(1) Correct defects of observation.
(2) Facilitate the association in the mind of the solid object with its flat representation.

Both this and the alternative plan enable the class to be kept together. By including within the section a number of examples and discussing them at the beginning, the exact order in which these are studied by individual students is unimportant. The best draughtsman should start with the more difficult details, and fill in time with additional sketching, drawing, or calculation. The next section is entered upon with all the students together.

It is a common plan to set all sorts of tricks in drawing views other than those given. Some of these are of practical value, and some are not. The latter form a cumbrous method of practising a student in reading a drawing—a faculty which can be more easily developed by associating object and drawing, and tested by giving the student a complicated drawing with instructions to get out some detail for the forge or machine shop.

In order to bring out the special features of the examples, the details may be compared with similar ones which are designed to meet a different set of conditions Thus an ordinary bearing for a horizontal engine may be compared with a locomotive axle box, a marine thrust block, and an adjustable bearing for a line of shafting. Roller and ball bearings, and bearings with ring oilers, should, however, be left until the second year. As a general rule, these examples introduced for comparison need not be drawn, but they must be sketched in the note-book. In this way some of the advantages of both methods of arranging the work is obtained. Details performing similar functions are grouped, and the general idea of the whole machine holds the knowledge together.

It should be observed that the second plan is the one more usually followed, mainly because the first is liable to involve drawings which are beyond the students' powers of draughtsmanship. Unless the possibility of the second method is kept in view, however, the examples selected may do nothing to develop a sense of fitness and proportion. If bearings are to be considered only in relation to 10 h.p. engines of a certain type, a connecting rod for a 1500 h.p. engine is out of place

as a detailed drawing in the same course. The set of drawings by one student which included a D slide valve, and a gas engine piston as the sole examples of these constructions, was a standing record of lack of system in the teaching.

Up to this point the value of workshop processes has been based upon the desirability of showing the student how the form and arrangement is dependent upon them. There are, however, other reasons. One is the encouragement which is given to the student to look about him in the shops. Teaching which only stimulates once a week is not worth a great deal, and no opportunity should be lost of putting the student into intellectual touch with his environment. It is unfortunate that the extreme sub-division of modern engineering industry permits few students to know exactly what goes on outside their own shop. More particularly is this the case with moulding. It has, therefore, been found very beneficial to include in this part of the course some instruction in moulding. Two methods have been adopted. One is to give demonstrations two or three times during the session just when the process has an important influence upon the design of the example studied. The casting is made in lead, and the plumbers' shop is utilized. The other plan is to include it as an exercise in the laboratory course, a few students being detached from the main body each week for the work. This may interfere with the laboratory course. The connection between the machine shop and the fitting shop—which supplies 90 per cent. of the students—is much closer, and few young fitters are ignorant of machine tools. If there is an Engineering Workshop in the school, however, some demonstration may be given with advantage on marking out, and on special machines and processes. It should be understood that machine construction is essentially a workshop subject, and it should reflect modern practice at every stage. This is the place to introduce limit gauges and other labour-saving devices which are often described in books on Applied Mechanics.

It will be obvious that in a scheme of this kind considerable judgment has to be exercised in selecting examples. Thus screw-threads should generally be represented in a conventional manner, and the accurate drawing of a thread relegated to the second year. Again, toothed-gearing is better deferred. The only cases in which this advice would be wrong are those in which the students are actually engaged in making screw-jacks, vices, or toothed wheels. Even then, in view of the difficulty of the drawing, they should not be introduced too early.

This question of drawing leads to another point, which it will be well to emphasize. If the order of the ordinary text-book is followed, the student is introduced rather early to examples which involve some skill in draughtsmanship—and require better instruments than he usually possesses Hexagonal nuts and bolts are not easy to draw well, and riveted joints afford scope for distinctly fine work. In the early stages it is most desirable that bold, simple examples drawn to a large scale should predominate.

The emphasis laid on the constructional side is liable to be interpreted as an excuse for inferior drawing This is a mistake. The practice in the past—owing to the influence of the examination and the traditions set up by the association of the subject with schools of art—has been to expect rather more complicated drawings than need be attempted. In the first year the students should confine themselves to simple types, but two points are essential—a sound knowledge of projection and neatness. Incorrect projections and slovenliness are not to be tolerated for a moment.

There can be no question that the foundation of these virtues is laid in the first six weeks of the session. If mistakes go uncorrected, and if untidiness and incomplete drawings are permitted during this period, the most unpardonable defects will persist to the end. For this reason all drawings which constitute the minimum for all students must be done at school,

and kept there. Work which is done at home is liable to all sorts of errors, which run a risk of being unnoticed or uncorrected.

A vigilant supervision must be exercised over the instruments. The pencils must be H or HH (preferably the former for beginners), and they must have a chisel edge. The argument that some draughtsmen prefer a round point has no significance here. What a skilled man can do with a round pointed HHHH pencil is no guide to what a beginner can do with a round pointed H, and a very hard pencil is for other reasons undesirable. Every student ought to have a small file or strip of sandpaper, and he ought to be encouraged to polish his point on a piece of hard paper before using. The first six weeks are a constant struggle against carelessness, and the teacher who is not something of a martinet at this stage will never achieve satisfactory results.

Every student should prepare ten or twelve good sheets of drawings during the session.

A final point arises in connection with the relation of the work to Solid Geometry. The latter subject it has been stated is generally omitted. But while there is no doubt that a great deal of engineering drawing can be accomplished without much geometry, the student loses by its omission. In a few schools the first five or six weeks are spent at simple construction and projection. This, however, leads to sins both of omission and commission. A better plan is to introduce the geometry as it is required. Some very good opportunities occur in drawing the curves formed at the ends of a connecting rod, and the quicker students might certainly plot these with advantage. In the second year more opportunities occur, and, in general the greater skill on the part of the student will enable him to attempt these with more success.

It seems hardly necessary to say that the school should not only have the requisite models and examples, but that it should be well provided with makers' price lists and catalogues.

The second-year course should contain a considerable amount of design, and here it is perhaps more desirable that the students should undertake a complete machine. All the drawings cannot, of course, be completed during the session, but the principal ones can be finished, and the rest will appear as sketches in the note-book. At the outside not more than half the time should be spent on drawing, the rest being taken up with sketching and calculation.

Some difficulty may arise in classes attended by students engaged in widely varying work. If the variety of students in the class is not too great, they can often be worked in sections. Two or three sets of students can generally be managed in a class of this kind without inconvenience, provided always that there is no external examiner with arm-chair views as to what each student should know at the end of each session. Should this mediæval form of tyranny exist, the school is condemned to a mediocrity for which the teacher is not responsible. A lame man cannot avoid a limp, and the only thing the writer can offer is sympathy

There are obvious reasons why students should not, even yet, go far away from their everyday experience. They will still be engaged in perfecting their observation and deepening that instinct which will enable them to formulate and use general rules in design, and for the present they must continue to examine more closely, and in greater detail, the machines through which they are obtaining their practical experience.

A very large percentage of the teachers of *Building Construction* are Manual Instructors Most of these will have had some industrial experience, and all are practised teachers. The details of presentation, therefore, call for less attention, and it will be desirable to confine observations to the scope and general attitude towards the subject.

Formerly the teaching of Building Construction consisted almost entirely of drawing from lithographed copies and from

diagrams in the text-book. Specimens were occasionally shown, and models were used to explain constructions which could not easily be made clear on the blackboard. No calculations were attempted, either of quantities or prices. Note-books were rarely kept, and still more rarely were they well-arranged, neat, and useful for reference.

The plan now being developed in many schools is much more practical. The essence of the teaching is construction. Models are not used to the same extent as in Machine Construction, but a good deal of work is done from actual measurement. Calculations, both of quantity and price, are included, and the student learns not only construction, but also the cost of construction. The most important examples are drawn to scale, and sketches of similar details or variations are made in a note-book.

Reference to Chapter VI. will show that the subject discussed here is one constituent of the course. On a second evening the student is engaged in the Geometry of Building—the office aspect, and on a third evening he is engaged in the laboratory in examining materials and becoming familiar with the scientific principles which underlie sound practice. This subject deals with practical work of the workshop, the yard, or on the building undergoing erection. It deals not so much with the minutiæ as with general arrangement, and the relation of the various trades.

The first section will deal naturally with sites. The character of the various soils and subsoils will be discussed briefly, and the special methods applicable to each will be outlined. The next few sections will deal with construction in brickwork, starting with foundations, and working upwards. Too much stress should not be laid upon varieties of bond at first. A simple bond having been selected, the wall of a dwelling is drawn up to the top of the door, showing the damp course and bearers in their proper position. After that an appropriate form of brick arch may conveniently be discussed and drawn. Then corbelling,

string courses, and other details which are appropriate to the upper part of a dwelling may be discussed, until the roof is reached. From time to time exercises will be set involving quantity of material and cost. The class should be asked to furnish data for the latter, and care should be taken to avoid treating this matter in too authoritative a fashion. Many of the examples should require merely an approximate answer, and attempts to secure a degree of accuracy neither warranted by the data nor necessitated by the nature of the problem should be checked.

It will be an advantage to defer the general discussion of bond and arches until after the whole wall has been completed. This tends to focus attention on essentials, and the subsequent treatment of variations revives and sharpens the original picture.

The next topic will be Masonry Construction, and this again revises the original section on Brickwork. Thus Masonry foundations and arches may be contrasted with those constructed in the material first considered.

Probably the next section will deal with floors—including various forms of fire-proof as well as wood floors. There will be no special treatment of joints in carpentry, these being considered in connection with appropriate construction. Similarly roofs, doors, windows, and other details will be dealt with by means of typical and appropriate examples, and subsequently amplified by sketches of variations in construction. In all cases the detailed drawings of joints should be shown to a large scale. Indeed, in order to avoid draughtsmanship which is beyond the capacity of the students or their instruments, it may be desirable to "break" the elevation, *e.g.*, of a sash in order to get the essential features to a sufficiently large scale in the first instance. As in Machine Construction, the session's work should be represented by ten or a dozen neat sheets of drawings, and by a note-book with sketches and descriptions which supplement them.

CHAPTER XIII

THE TRAINING OF THE TECHNICAL TEACHER.

THE title at the head of this chapter states a problem which is becoming of greater and greater importance. Every year sees an addition to the difficulties which Technical Schools have to face. The growth of scientific knowledge and the increasing sub-division of industry render the task of providing adequate training for those who can only devote a limited time to study one of greater and greater difficulty. The teacher is called upon to exercise a profounder judgment as to what shall and what shall not be included, and his ingenuity is taxed to find the most efficient and economical method of achieving a desired result. Some indication of the variety of types of men who are at the service of the Technical School has been given in Chapter III. The staff, moreover, is constantly changing. The older men are dropping out owing either to age or to industrial or professional claims, and their place is taken by young men who, prior to their appointment, have thought little about the duty they will have to discharge. The disastrous effect is easy to realize whether teaching is regarded wholly as an art or is acknowledged to have a scientific basis. For every art is more readily acquired when the young workman is first shown how to use his tools, and every science demands some preliminary study of phenomena, materials, and processes.

It will be desirable to glance briefly at the provision which has hitherto been made for training technical teachers in this country. For many years the Science and Art Department

awarded studentships to teachers and intending teachers who were able to devote a whole year to study at the Royal Colleges of Science in London and Dublin. Grants-in-aid were also made to teachers who undertook to attend for not less than two days a week at certain Universities and University Colleges. In this way a number of teachers obtained instruction which they would otherwise have lacked. They had the advantage of attending lectures by distinguished men, and of working in well-equipped laboratories. They frequently took home the instruments they had made, and used them effectively in their classes. But beyond obtaining experience of the methods of teaching older students who had acquired the rudiments of a subject, they brought away no hint which would be of value. Certainly they received no assistance in breaking new ground with beginners.

The establishment of preliminary courses in evening schools necessitated the adoption of special methods—more particularly in Practical Mathematics—and since 1902 several Local Education Authorities have instituted courses in which the main object was to train teachers for this work. They have been held during the winter months and in short summer courses. Those who attended were generally engaged in elementary schools, and the method adopted was to work through exercises of the kind which would be given subsequently to their students. This involved some hint as to the order of treatment and the method of presentation. At the same time the dominant aim was an increase in the teacher's own knowledge of and skill in his subject rather than the establishment of method on a sound scientific basis; the classes were attended by teachers who had already received some professional training, and they left the special problem of the training of the Technical Teacher untouched.

The enormous spread of scientific training and the lavish provision of scholarships in recent years have largely obviated

the necessity for the plan first outlined. There is now very little difficulty in securing men whose academic qualifications in the subjects they are required to teach are, on the whole, satisfactory. Perhaps some exception should be made in regard to Mining, but in a general way it may be said that what is often lacking is general education rather than special knowledge. At any rate, it will simplify what follows if it is assumed that there is a sufficiency of men whose knowledge of their subject is well above the standard to which they have to teach.

It may be supposed that every one knows there are good and bad teachers, and that many improve very considerably with practice. This is the case with every art when it is pursued conscientiously and thoughtfully. A man who does not improve is either careless or incapable of thinking. But it is obvious that as things are a teacher is left to improve or not according to chance. He is appointed as a raw hand, in fear and trembling, and a fervent prayer that he may turn out all right is breathed by those who select him. If he is successful, well and good. The august body who perceived his innate and untried excellence congratulate themselves. But if he should fail, a successor is looked for. It is of no consequence that such a man, placed for a session under the supervision of an experienced teacher, might have been a brilliant success. There is no machinery for an apprenticeship of this kind. The arrangement of a scheme of instruction to occupy some thirty lessons, the way in which each portion of the subject should be approached, the relation of laboratory work, drawing, or workshop practice, to theoretical teaching, the position of his subject in the curriculum of the school, the function of home-work—all these are matters which he is supposed to have acquired with his milk-teeth or in his subsequent career as a student, when his business was not teaching but learning. Surely something should be done, if not for his sake, at least for that of the students committed to his care!

Against this it may be argued that his case is only a replica of that of all other Technical Teachers. Every man who aspires to be a Technical Teacher submits to this Ordeal by Fire. But what is the result? How many teachers possess an adequate knowledge even of the points enumerated in the last paragraph? How many teachers strike the right balance between lecturing and teaching? How many conduct theoretical and practical work as though they were separate subjects? How many regard drawing as an end rather than a means to an end? How many set home-work promiscuously? Is there any other profession in the wide world in the practice of which a man depends upon Heaven-born instinct and is allowed to ignore the accumulated experience of his predecessors?

But even if it be granted that some training is desirable, it may be urged that if all Technical Teachers have been trained in this way they are not competent to undertake the training of those who are to carry on and improve upon their work. This is only partially true. In a large measure teaching is a Practical Art. A man may be shown what to do and how to do it. He may be shown what errors experience suggests should be avoided, and how to avoid them. And while this falls far short of the ideal which a professional teacher should set before himself, it would still be beneficial to the Technical Teacher. For though the latter works under certain disadvantages, there are compensations. Few evening students come to school for fun. They are keen. In many cases they can use a text-book. Matters which they do not understand in class they solve in the privacy of their homes, or by discussion with their companions. An unskilful teacher may hamper a student, but the really clever youth will succeed in spite of him. On the other hand a teacher who works on a correct empirical basis can smooth the way and turn learning from drudgery to pleasure. For the sake of efficiency and economy in the public service he ought to be helped to do it.

Of course if the matter is pressed to its logical conclusion, this is a very low expression of requirements. For the business of conducting beginners into new territory the teacher should possess a full and accurate conception of the ways in which a man acquires knowledge and skill. He should be familiar with the conclusions of Modern Psychology, so far as they affect school practice. He should be acquainted with what is known as to the nature of knowledge, the mechanism of thought, the doctrine of apperception or association, and the phenomena of imagination and memory. Moreover, he should have read some logic, and have acquired some facility in analysis, classification, and arrangement. If he is a teacher of Mathematics or Physical Science he should have read some of the books which deal with the philosophical basis, as well as with the dry bones of fact and phenomena.

But merely reading books or listening to lectures will not make a man a teacher. Mathematics alone will not make a man an engineer, nor Physiology a doctor. Mathematics and Physiology are essential, but are useful only in so far as they are interwoven with general practice. The way to learn teaching is to teach. He who *uses* the most Psychology, not he who *knows* the most, is the most effective teacher, for this amount represents the scientific measure of his practice.

It will be obvious that there is no intention here to assert that without an intimate fabric of academic theory and practice a man cannot teach. Experience in a practical art always counts for much. Many men have a sound knowledge of their subject, an inspiring manner, a habit of clear expression. They are interested in their work, sympathetic with and observant of their students, quick to appreciate difficulties of comprehension, and ready to devise new ways of presentation whenever the need arises. In time they acquire methods which are educationally sound, and which they are able to defend from the facts and phenomena of experience. If such men were required to

systematize and explain their knowledge of method they would use in every case in which they were correct a nomenclature which, if not exactly the same, would correspond very closely to the language of Psychology. To that extent is the statement true that Psychology enables a man to state familiar knowledge in an unfamiliar tongue. But the professional Psychologist is probably a greater adept at terminology than the amateur.

However, this standard of perfection is rare, and the great majority of untrained (with many trained) teachers incorporate into their practice much that they would omit if they had a fuller acquaintance with mental science. They and their students are continually meeting with difficulties, the real nature of which is not recognized. The subject is hard, or the students are stupid; the conscientious teacher is discouraged, and the other sort has emotions which are not worth discussing.

To come now to practical details. The main recommendation is that young men who possess the necessary personal qualities should have the privilege of conducting one or more classes for a year under the supervision of experienced teachers. Incidentally they would learn something of organization, and they would receive criticism and advice in the preparation, delivery, or management of lessons. They would have some one to consult in case of difficulty, would make conscious progress, acquire confidence, and develop professional zeal. But in addition to this, they ought to have some systematic instruction in the general principles of teaching and in their application to a particular group of subjects. This could be given either during the winter or in a short summer course

In view, however, of the highly specialized character of Technical Teaching, no one town could provide a sufficient number of students to justify a separate class of this kind, and it would be necessary to fix centres which would serve a wide area.

The chief difficulty, of course, is to find teachers for this

theoretical training. Most, if not all, Technical Teachers treat the matter from the point of view of the subject, and fail to recognize the mental idiosyncrasies of the student at all. Men who understand the theory of teaching ordinary school subjects are ignorant of technical subjects ; competent Technical Teachers are still frankly empirical. If the empiricist only propagated sound maxims one could forgive him, but the greater the number of these merely increases the danger of authoritative error. At first sight there appears to be a possible solution. That is for certain men with technical knowledge to undergo a course of training in the Theory and Practice of Teaching. But Logic and Psychology are not Teaching, though necessary to it, and they are only of value in so far as they are incorporated in practice. Experience with trained teachers shows that this takes time, and the old and the new would not coalesce immediately. Nothing can be worse than ill-digested academic Psychology as a basis of teaching. It is recognized that Pure Mathematics is meat for few and poison to many. In the same way where one Technical Teacher would profit from Psychology ten would derive greater benefit from a model. And if such models can be not only free from serious error, but can be accompanied by such explanation as will enable the young teacher to distinguish good from bad, and the why and wherefore, they will achieve a useful purpose.

While this last consideration has determined in large measure the character of this volume, it is recognized that some teachers may wish to go to the fountain-head, and it may be useful to close this chapter with the titles of a few books which may be studied with profit.

Probably the most suitable work on Psychology is that by William James. The briefer course will be found sufficient. The close association between the physical and mental life which pervades James's books will appeal to a man who has had a scientific rather than a philosophical training. For those who

prefer an easier book the same author's "Talks to Teachers" would prove interesting. Both these volumes present the subject from an introspective point of view, and in that respect differ considerably from those by writers of the Herbartian school, whose methods are synthetical rather than analytical. Of these perhaps Professor Adams's "Herbartian Psychology applied to Education" is the most suitable, but no man without a sense of humour should attempt to read it. The book bristles with stories and anecdotes, which float in a matrix of none too easy philosophical discussion. Its conclusions are incidental rather than prominent, and it is as much unlike a dry text-book as it well can be. None of these books contain a statement of the four (or five) step method of teaching. A short outline is contained in Raymont's "The Principles of Education," and a fairly full illustration of its application to History and Pure Geometry in Findlay's "Principles of Class Teaching."

Another invaluable book is Welton's "Logical Bases of Education," and no teacher could fail to benefit from reading and reflecting upon the nature of knowledge, and the various types of reasoning, which are illustrated by a wealth of examples, selected from a wide field.

Turning from general principles to special method, we have to acknowledge an extraordinary scarcity. Almost the only subject which has been treated from the psychological as well as from the subject standpoint is Mathematics. Here Dewey and M'Lellan's "Psychology of Number" is an interesting though rather difficult book. As the name implies, it deals with number almost entirely, and leaves largely untouched the wider field of Mathematics. Still it is systematic and suggestive. Branford's "The Study of Mathematical Education" is a more recent and extremely suggestive book of much wider scope. It is in places unsystematic, but it represents the best and far the most scholarly attempt with which the author is acquainted to develop on a scientific basis the theory of teaching

the subject. It should be understood that neither of these books have in mind the special needs of technical students, which have been dealt with in a more empirical way in Perry's "The Teaching of Practical Mathematics." The value and the limitations of Perry's views are, however, much clearer when they are studied in connection with the two books to which reference has been made. Probably no subject has suffered more in recent years from misinterpretation than Practical Mathematics.

The teacher of Mechanics and Mathematics needs some knowledge of the philosophical foundations of his subject if he is to avoid the many pitfalls that are inseparable from the violent changes of scope and method which are now in progress. One of the most delightful books that was ever written is Clifford's "Common Sense of the Exact Sciences," and it ought to be on every teacher's bookshelf. Similarly Mach's "Mechanics" is suggestive and stimulating, and Karl Pearson's "Grammar of Science" should be added. The list might be extended considerably without a corresponding increase in value. But the teacher who wishes continually to improve the method and effectiveness of his teaching should realize that much depends upon the breadth of his own reading and the depth of his own thought.

After all no one can be taught how to teach; he can only be placed in the way of making himself a teacher. It is practice combined with knowledge of, and reflection upon, what others have done, a frank and generous comparison of his own and other people's methods, sympathy with his pupils, and a knowledge of their interests, their difficulties, and their aspirations—these alone will enable him to achieve success in the noblest and most inspiring profession that falls to the lot of man.

QUESTIONS

1. Write out a list, in proper teaching order, of typical examples which you would use for a first-year class of Machine Drawing Students who were engaged in either—

(a) A works manufacturing hydraulic machinery.

(b) A works engaged in constructive work, bridge building, etc.

(c) A marine engine works.

(d) A gas engine works.

(e) A machine tool works

(f) A textile machinery works

(g) A central electric power station.

(h) A steel works, or

(i) An agriculture implement or engine works.

2. In the particular industry selected in Question 1 choose one type of construction and give a list of other similar details which you would discuss in a section in order to widen the students' knowledge.

3. At what stage or stages in your scheme would you introduce forging ?

4. At what stage or stages in your scheme would you discuss moulding ?

5. Why are models or actual specimens necessary in teaching Machine Construction or Building Construction ?

6. What are the advantages of experimental work by the students themselves ?

7. A teacher proposes to deal with the elasticity of a gas. He starts by writing " Boyle's Law " on the blackboard Is this wrong ? If so, why ?

8. What is the difference between words and knowledge ? Should the words or the knowledge come first ?

9. Compare the lesson on Porosity and Capillarity on page 69 with one in which the teacher starts with the immersion of a narrow tube in water. Why is the latter method wrong, and in what respects will it probably be a failure ?

10. What is the purpose of the Drawing in Machine Construction and Drawing ?

11. Under what circumstances is Laboratory work unnecessary ?

12. A teacher commencing the study of Mechanics with a class began with statics, and used as an example two forces acting at right angles on a billiard ball. Why was this wrong?

13. In the lesson of Question 12 one of the students—an adult artisan—asked if the two forces could be taken as acting along the arms of a governor. What was this student's difficulty? Why was the teacher wrong to say No and to continue his own method?

14. Why is it foolish to set an elementary class to determine areas by weighing?

15. Draw up notes of a lesson on the elasticity of solids.

16. Why is it unnecessary to specify the three orders of levers?

17. What are the advantages of doing Solid Geometry and Trigonometry side by side?

18. What are the advantages of starting with horizontal projection in Solid Geometry?

19. How would you introduce the Co-ordinate Geometry of the straight line?

20. Give illustrations from any subject you teach, of the way in which you prepare the ground for the reception of new knowledge.

21. A teacher of Practical Mathematics once complained that his students were slow in multiplying and dividing, and uncertain in fixing the decimal point. To remedy this he set them to measure up and calculate the surface and volume of wooden blocks. Explain—

(a) What particular value the practice of measuring up and calculating area and volume has;

(b) How the defect should have been remedied.

22. Draw up a lesson on the water-gauge for a class of coal-miners.

23. What are the disadvantages of the plan of teaching Applied Mechanics and Heat Engines in alternate lessons?

24. What are the disadvantages of teaching Practical Mathematics and certain parts of Geometry separately?

25. Draw up notes for a series of lessons or section dealing with Specific Gravity.

26. What experimental exercises would you include in a section devoted to acceleration, and in what order should they be performed?

27. What use would you make of models in a Building Course? What models do you consider indispensable?

28. A teacher found, in an elementary class, that his students were unable to give him a definition of the circle as a figure bounded by a locus; so he set them to draw circles and ellipses with a loop of thread and pins. They afterwards readily stated that the circle was a curve in which every point was equidistant from a given fixed point.

What was their original difficulty, and in what way did the teacher's plan help them?

29. Mathematics teacher.—State the mathematical operation in which you desire your students to have practice in, say, the seventh week of the session.

30. Mechanics teacher.—Write out four questions which will give the mathematical practice required in above question, and which will be appropriate to the stage of progress reached in your class.

31. Machine Construction teacher.—At an early stage in the session the teacher of mathematics proposes to deal with the mid-ordinate rule for the area of irregular figures. Can you supply him with problems which have arisen in the Machine Drawing class, and which will serve as a starting point?

Give two or three examples if you can

32. Write out a first-year course in Chemistry suitable for students who are engaged in alkali and copper works.

33. Write out a first-year course in Chemistry suitable for young men engaged in iron and steel works.

34. What steps would you take to develop the power of taking notes (*a*) in the classroom, (*b*) in the laboratory?

35. Some students are much quicker in Drawing and Laboratory work than others. How do you meet this difficulty without having recourse to individual teaching?

36. The teacher of a class in Mechanics has only one piece of apparatus for a certain experiment. Should he let each pair of students use it in turns, or should he make it the subject of a demonstration? Discuss the pros and cons.

37. A first-year class in Applied Mechanics had only done about seven experiments each in four months. Is this sufficient?

38. The explanation of the result in the last question is that the students have been thrown upon their own resources. Discuss the advisability of this.

39. Building Construction teacher.—State the geometrical constructions which you would like to accompany the first ten lessons of your Building class.

40. Building Construction teacher.—State the geometrical constructions you would like your students to know—

(a) In the first year.

(b) In the second year.

41. Building Construction teacher.—In the two foregoing questions suggest examples which the teacher of Geometry might use.

42. Draw up notes of a section in Mechanics for Builders dealing with lifting appliances.

43. What are the disadvantages of lantern slides in teaching?

44. The preface to a book on Practical Mathematics draws attention to the fact that Mathematics was originally a practical art, and that when man had leisure he pursued it as an intellectual pleasure. It then goes on to suggest that the evening student just joining the Technical School is similarly placed to the unemancipated savage. Discuss this.

45. Draw up a first-year course in Chemistry suitable for students engaged in bleaching, dyeing, and calico printing works.

46. Draw up notes on a section dealing with electrolytic dissociation showing clearly the steps of preparation, presentation, formulation, and application.

47. Draw up a short course of electricity leading to the above question.

48. Should the electrolytic decomposition of water ever be used as a proof of the composition of water? Why not?

49. Draw up a short course on the Chemistry of Fuel and Combustion to be delivered in the summer term to Engineering students who have done the ordinary first or second year course (T_3 or T_4).

50. Draw up notes of a section on Ventilation for Builders. What would you expect them to know beforehand? Set three numerical exercises to follow as homework.

51. Why does an explanation of limit gauges belong to the Machine Construction teaching rather than to that in Applied Mechanics?

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